"In presenting the dissertation as a partial fulfillment of the requirements for an advanced degree from the Georgia Institute of Technology, I agree that the Library of the Institution shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to copy from, or to publish from, this dissertation may be granted by the professor under whose direction it was written, or, in his absence, by the dean of the Graduate Division when such copying or publication is solely for scholarly purposes and does not involve potential financial gain. It is understood that any copying from, or publication of, this dissertation which involves potential financial gain will not be allowed without written permission.

THRESHOLD VALUES FOR RESONANT ACOUSTIC VIBRATIONS ON CONVECTION HEAT TRANSFER IN A HORIZONTAL, ISOTHERMAL TUBE

A THESIS

Presented to

the Faculty of the Graduate Division

by

Ian Eastwood

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Mechanical Engineering

Georgia Institute of Technology

September 1961

3a
12R

THRESHOLD VALUES FOR RESONANT ACOUSTIC VIBRATIONS ON CONVECTION HEAT TRANSFER IN A HORIZONTAL, ISOTHERMAL TUBE

Approved:

Calvin C. Oliver

Kenneth R. Purdy

Jack M. Spurlock

Date Approved by Chairman Sept. 7, 1961

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Professor C. C. Oliver, who was his Thesis Advisor, and to Professor K. R. Purdy for their valuable assistance and warm encouragement. The cooperation of Dr. J. M. Spurlock, of the School of Chemical Engineering, who served as a member of the reading committee, is gratefully acknowledged. The author would also like to express his deep gratitude to the Georgia Tech World Student Fund Committee and to all members of the faculty and student body for making this visit to the United States of America such a worthwhile and enjoyable experience. Finally, thanks are due to Dr. T. W. Jackson, of the Engineering Experiment Station, who provided a graduate research assistantship which enabled the author to complete this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

NOMENCLATURE

Latin

A	=	inside surface area of tube, ft.^{2}
c_p	=	specific heat at constant pressure, BTU/lb.°F.
D	=	inside diameter of tube, ft.
d	=	orifice diameter, in.
g	=	acceleration due to gravity, ft./hr.^{2}
h	=	heat transfer coefficient of convection, BTU/hr.ft.^{2} °F.
h_{fg}	=	latent heat of vaporization, BTU/lb.
H_w	=	differential pressure across the orifice, in. of water.
k	=	thermal conductivity, BTU/hr. ft. °F.
K	=	orifice discharge coefficient, dimensionless.
L	=	length, ft.
m	=	mass of condensate, lb.
$\dot{m}$	=	mass rate of flow, lb./hr.
p	=	pressure, in. of Hg.
P_{max}	=	maximum local acoustic pressure, lb./ft.^{2}
Q	=	heat transfer, BTU.
SPL	=	sound pressure level, decibels (db).
t	=	temperature, °F.
u_{max}	=	maximum local acoustic velocity, ft./ sec.
$\bar{V}$	=	air velocity, ft./sec.
v	=	specific volume, ft.^{3}/lb.

x = axial distance from the tube entrance, ft.

Y_1 = expansion factor based on absolute static pressure at the upstream pressure tap, dimensionless.

Greek

α = area multiplier which allows for thermal expansion or contraction of the orifice plate, dimensionless.

Δ = indicates an increment.

γ = specific humidity, lb./lb.

μ = dynamic viscosity, lb./ft. hr.

ν = kinematic viscosity, $ft.^2/hr.$

ρ = density, $lb./ft.^3$

τ = time, sec.

Subscript

a . . . refers to condition of air.

am . . . refers to arithmetic mean.

d.b. . . dry-bulb.

e . . . refers to blower delivery conditions.

i . . . refers to chamber number.

ℓm . . . refers to log mean.

o . . . refers to entrance conditions.

oa . . . refers to first 0.38 inches of tube.

s . . . refers to conditions at inside surface of tube.

x . . . refers to local values.

Moduli

Nu	Nusselt, based on the tube diameter and wall properties, $(hD)/k$.
Re	Reynolds, based on the tube diameter and on tube inlet conditions, $(\rho_o \bar{V}_o D)/\mu_o$.

SUMMARY

The purpose of the investigation was to determine critical sound pressure level values for the combined effects of resonant acoustic vibrations and simultaneous convective heat transfer in an isothermal, horizontal tube. This work is an extension of previous work done by Jackson et al.(2 and 3) in a similar system, and is restricted to plane longitudinal sound waves.

In order to determine the relative effects of acoustic vibrations on heat transfer rates, one no-sound and three or four sound runs at various sound pressure levels and constant resonant frequency were conducted for each Reynolds number. Experimental local heat transfer coefficients for the no-sound condition were found to be approximately 20 per cent greater than the theoretically predicted values. Data are reported for a resonant frequency of 222 cps and for Reynolds numbers between 16,000 and 200,000. The highest sound pressure level that could be obtained at this frequency was 164.5 decibels. The local heat transfer coefficient is shown to vary periodically between the nodes and loops of the standing wave. For Reynolds numbers below approximately 20,000 the maximum local Nusselt numbers occur at the velocity loops; above 35,000 the maximum values shift to the velocity nodes. This shift appears to gradually take place between Reynolds numbers 20,000 and 35,000, and within this range of values the effects of resonant acoustic vibrations on heat transfer rates appears to be relatively small. With

reference to overall heat transfer rate, above a Reynolds number of approximately 35,000 super-critical sound vibrations tend to suppress the overall heat transfer rate. For a Reynolds number of 16,100 there was no appreciable effect of sound on the overall heat transfer rate. At Reynolds numbers greater than about 100,000 no measurable effect of sound on the heat transfer coefficient could be determined with the frequency and sound pressure levels tested.

Critical sound pressure level values for a resonant frequency of 222.0 cps were obtained for various Reynolds numbers in the range 16,000 to 76,000. These critical values fell into two distinct regimes when plotted versus the corresponding Reynolds number, and in each regime the critical value was directly proportional to the Reynolds number. The empirical relation found may be summarized in two equations:

$$SPL_{crit} = 2.33 \times 10^{-4}\ Re + 151 \quad \text{for} \quad Re < 35{,}000,$$

$$SPL_{crit} = 2.25 \times 10^{-4}\ Re + 141 \quad \text{for } 35{,}000 < Re < 76{,}000\ .$$

It is interesting to note that the discontinuity occurs at approximately a Reynolds number of 35,000, which practically coincides with the end of the phase shift.

The reason for the shift in phase and for the existence of two regimes for critical sound pressure level values is not clear at this time, and no attempt was made at an analytical solution. However, it appears feasible that different heat transfer mechanisms are involved in each regime, and tend to cancel each other out in the range of

Reynolds numbers roughly between 20,000 and 35,000. Experimental results obtained and various graphs are given in the Appendices.

CHAPTER I

INTRODUCTION

Statement of Problem.--A program to study the effects of combined acoustic vibrations and simultaneous heat transfer was initiated at the Mechanical Engineering Laboratories of Georgia Institute of Technology in 1959, under the sponsorship of the Aeronautical Research Laboratory at Wright Field. Investigations (1, 2, and 3)* revealed the existence of critical or threshold sound pressure levels, levels below which there were no observed effects on heat transfer due to resonant acoustic vibrations. The critical sound pressure level appeared to be a function of the Reynolds number, but experimental data were limited by the apparatus to Reynolds numbers and sound pressure levels (SPL) less than 11,600 and 162.5 decibels, respectively. A survey of the related literature revealed that no experimental data have been obtained for higher values of Reynolds numbers and sound pressure levels; therefore, a series of experiments were initiated in order to extend the range of information.

Object.--The purpose of the investigation was to determine experimentally critical or threshold values of sound pressure level for resonant acoustic vibrations on convective heat transfer in an horizontal, isothermal tube. The desired result was to obtain an empirical relationship between critical sound pressure level and Reynolds number, for values as high as possible.

---

*Numbers in parentheses refer to references in the bibliography.

Scope.--The work reported here is entirely of an experimental nature, and no attempt is made to obtain an analytical solution. It must be emphasized that only the effects of plane longitudinal acoustic vibrations were considered. The controllable variables in the experiments were: air flow rate, sound pressure level, and frequency. The resonant frequency was kept constant, and the air flow rate and sound pressure level were varied to obtain a relationship between critical sound pressure level and Reynolds number. Preliminary investigations made on the sound generating equipment indicated that at high resonant frequencies (1500 cps) only relatively low maximum SPL were obtainable. Consequently, as high SPL were desired, tests were conducted at a lower resonant frequency, roughly 220 cps, which coincided with the fourth harmonic for an open pipe. Maximum air velocities considered were restricted to a Mach number of 0.1.

Survey of Related Literature.--Interest in the effects of combined acoustic vibrations and simultaneous heat transfer in free and forced convection has been stimulated in recent years by the failure of tail pipes on jet aircraft and rocket engines. Good surveys of the early and contemporary experimental and analytical work carried out in this and related fields are given in references (2) and (4). References to other related investigations are given in the bibliography.

The work reported on here is an extension of the investigation made by Jackson, Purdy, and Oliver (3) on the effects caused by plane longitudinal vibrations. This investigation was conducted for Reynolds numbers in the range 2,040 to 11,600, for three resonant frequencies:

171, 221, and 356 cps; and it was found that for resonant conditions, the sound waves produced a periodic effect on the local heat transfer coefficients. The variation appeared to be a function of the half wave length of the impressed resonant vibration, with maximum values occurring at the velocity loops of the standing sound waves, and the minimum values at the velocity nodes. Two critical sound pressure level values were obtained experimentally; for a Reynolds number of approximately 2,100 and 221.0 cps, the critical value was 152.0 decibels. For a Reynolds number of 11,600 and 216.0 cps, there were no effects observed below 153.5 decibels. Furthermore, it was found that though the effects of high sound pressure levels on the local heat transfer coefficients were very pronounced, the increase in the overall values was relatively modest. For instance, at a resonant frequency of approximately 220.0 cps and a SPL of 162.5 decibels, an increase of 20 per cent was noted in the overall heat transfer coefficients for a Reynolds number of 2,100. At a Reynolds number of 11,600 the increase in the overall value was only 13 per cent.

CHAPTER II

APPARATUS

A schematic diagram of the experimental equipment used is shown in Fig. 1. Essentially it was the same equipment and arrangement used by Jackson, et al. (3), except for modifications made on the air supply and sound generating equipment.

Briefly, the apparatus consisted of a steam heated test section and an electronic system for producing and measuring a stationary acoustic field.

The various components were:

1. Heat Transfer Apparatus
   (a) Steam heated tube.
   (b) Condensate collection system.
   (c) Air supply system.
   (d) Thermocouples and potentiometer.
2. Sound Generating Equipment
   (a) Drivers and horn.
   (b) Audio signal generator and smplifier.
3. Sound Measuring Equipment
4. Acoustic Shield

1. Heat Transfer Apparatus

The test section was a 10 foot, 6 inch long, 4.125 inch outside diameter copper tube, surrounded by a 16-inch standard steel pipe forming an annular space or steam chest. Saturated steam was allowed to circulate around the steam chest, and this ensured that the outside of the tube was kept isothermal. The condensate was collected around the periphery and along the tube, by twenty-one evenly spaced collection chambers, the contents of which were drained via transfer cups into burrettes, where the volume collected was measured as a function of time. The burrettes were attached to a rack located outside the acoustic shield. A detailed description of the steam heated tube and condensate collection system is given in reference (2).

The air supply and metering system consisted of an air filter, a 28-inch diameter American Blower driven by a 15-horsepower Allis Chalmers electric motor, a throttling device, an orifice plate, a mixing chamber, and an inlet plenum chamber. Because of limited space, it was found necessary to locate the blower and orifice plate outside the acoustic shield in the laboratory. The throttling device was a cone shaped, variable throttle valve connected to the blower intake. Air drawn from the laboratory passed over a hygrometer attached to the filter box, which enabled the specific humidity to be determined from the wet- and dry-bulb temperature readings. The blower delivery was connected to a straight 6-inch nominal diameter (schedule 40), 6 foot 8-1/2 inch long steel pipe. A thermometer well containing a mercury in glass thermometer and a pressure tap connected to a 24-inch mercury manometer were used to find the temperature and pressure, respectively, of the air upstream of the orifice plate. Slip-on flanges, with flange pressure taps and a standard ASME orifice plate, were connected to the end of the steel pipe.

Depending on the flow rate, pressure taps for the orifice were connected either to a 48-inch differential water manometer or to a 12-inch micro-monometer. It was found necessary to use two different orifices to meter the air flow in the range of Reynolds numbers investigated, 16,100 to 135,000. For Reynolds numbers greater than 35,000 the orifice diameter ratio, that is the ratio of orifice diameter to the inside diameter of pipe, was 0.5. For Reynolds numbers less than 35,000 the orifice diameter ratio was 0.225. The leading edge of both orifices was square and sharp, and the upstream faces were machined smooth. The distance between the blower and the orifice plate was approximately equal to 13 straight pipe diameters plus the straightening tubes. Downstream of the orifice there was a section of straight pipe equivalent to 5 pipe diameters. These distances were greater than the minimum quoted in reference (6), and other specifications laid down in this reference regarding construction, layout, and measurement were followed.

After the orifice, another straight section of pipe and an elbow passed the air through the wall of the acoustic shield into the mixing chamber, where the air temperature was measured. The mixing chamber was made from 1/2-inch plywood, and the approximate dimensions were: 2-feet long, 1-foot wide, 1-foot deep. The air flowed through two, 2-inch diameter pipes connecting the mixing chamber with the inlet plenum. Provision was made in the connecting pipes for inserting various sized orifices; this was required for runs at the lower Reynolds numbers because the inlet throttle valve did not reduce the flow sufficiently. The inlet plenum was constructed from 3/4-inch plywood and was well insulated to prevent changes in air temperature before entering the test section. Air entered the copper test tube via a bell-mouthed section made from mahogany. This ensured that the velocity at the tube entrance was uniform, and also insulated the entering air from the hot head plate of the tube. The air leaving the test section was exhausted directly into the laboratory.

The temperature of the air in the mixing chamber was measured with a 24-gauge iron-constantan thermocouple connected to a Leeds and Northrup Speedomax H direct reading temperature indicator. Twenty-four-gauge copper constantan duplex thermocouples were used to measure the steam and tube wall temperatures. The emf produced was measured by a Leeds and Northrup 8686 Millivolt Potentiometer.

2. Sound Generating Equipment

A schematic diagram of the sound generating equipment is shown in Fig. 2. A RCA Model WA-44B audio signal generator was coupled to two Bogen, Model CHA 75, 75-watt amplifiers. Each amplifier was connected separately to a fifty-watt PA-HF University driver. The drivers produced the sound field in the test section, and the power supplied to each driver was measured with a Heathkit, Model AW-1 audio wattmeter, and on an Eico, Model 425, push-pull oscilloscope. A Sorensen, Model 2501, voltage regulator supplied 115-volt, 60-cycle power to all instrumentation.

The horn used on the drivers was made from sheet metal and had a conical configuration, 18 inches long and an outlet diameter of 2 inches. Fig. 4 shows how the horn and drivers were positioned on the rack. The location of the horn in the test section could be adjusted by means of a hand-crank, which worked through a set of pinions to move the rack axially. The maximum sound pressure level achieved with this system, at an audio-frequency of 222.0 cps, was 164.5 decibels.

3. Sound Measuring Equipment

The sound pressure level was determined as a function of position by inserting a microphone, mounted on the end of a 15-foot aluminum rod, into the test tube. A calibrated sound level meter gave a direct reading of the sound pressure level in the tube. Details of the components of the sound measuring equipment are to be found in reference (2).

4. Acoustic Shield

The acoustic shield, an eight-by-twenty-foot room, eight feet high, was built to enclose the test apparatus in order to reduce the sound pressure level in the laboratory to a safe level. The room had a two-by-four wood framework with double layers of 3/8-inch sheetrock inside and outside. In the door facing the inlet air plenum chamber, a removable plug was inserted so that the sound pressure level probe could be inserted. A photograph of the shield is shown in Fig. 5.

CHAPTER III

EXPERIMENTAL PROCEDURE

In order to determine the relative effects of acoustic vibrations, a no-sound run and three or four sound runs at various SPL were conducted for each series of constant Reynolds number. The experimental procedure was divided into the following three phases:

1. Test Runs Without Sound

Heat transfer runs without sound were conducted to ascertain the accuracy and reproducibility of the apparatus. Test runs were initiated by first adjusting the air flow rate, and the steam pressure, until the desired settings were attained. At the lower Reynolds numbers the apparatus was allowed to run for almost two hours before taking any readings; this period enabled thermal equilibrium to be established. At the higher Reynolds numbers the "warming-up" period was reduced to an hour.

To start an actual test run, the burrettes were first drained, a stopwatch was started, and the initial burrette readings were noted. The burrettes were read at fifteen minute intervals for the first three quarters of an hour, and at half-hour intervals thereafter for the remainder of the test run, which varied in time between two and two and a half hours. The temperature of the air in the mixing chamber and the pressure drop across the orifice plate were recorded at half-hour intervals. The following readings were taken at approximately hourly intervals: wet- and dry-bulb temperatures, barometric pressure, steam temperature and pressure, test tube wall temperatures, and the temperature and pressure upstream of the orifice plate.

All readings were averaged for the duration of the test run, and the values obtained were used in the calculations, unless erratic discrepancies were evident in either the condensate flow rate or in any of the pressure and temperature readings.

2. Preliminary Test with Sound and No-Through Flow

Tests without through flow but with the sound equipment on were made to determine the resonant frequencies of the test tube, and to find the axial distribution of the sound pressure level in the tube. A distribution obtained for a particular resonant frequency and signal generator output is shown in Fig. 3. Fig. 3 essentially shows the resultant or superposition of the sinusoidal input sound wave and the reflected wave which has a tendency toward a saw-toothed configuration. This configuration arises from the wave pressure peaks experiencing a local acoustic velocity slightly greater than that of the wave at the mean point, hence the peak tending to overtake the mean point of the wave. A mathematical treatment is given in reference (7).

3. Test Runs with Combined Sound and Through Flow

Data taking sound runs were conducted in a similar manner to the no-sound runs, except that the sound generating equipment was adjusted before starting. The microphone probe was inserted into the tube, in the position where the first maximum SPL was observed during the preliminary tests, and fine adjustments to the resonant frequency and the desired SPL were made. Immediately after, the probe was removed from the tube and stored in the entrance plenum box to minimize air flow distortion.

Approximately an hour was allowed for steady conditions to be established, and an actual data run was started in the same manner described for the no-sound tests. At the end of a data run, about two hours, the tube was again probed to check the maximum SPL in the tube. As in the case of the no-sound runs, the average values for all readings were used in the calculations.

CHAPTER IV

CALCULATION PROCEDURE AND NUMERICAL RESULTS

The volume flow rate of air through the test section was found from the orifice equation for standard ASME orifice plates. The equation for the flow rate in cubic feet per hour is:

$$W = 359.1\,(d)^2\,\alpha \cdot K \cdot Y_1 \cdot \sqrt{v \cdot H_w}\,. \qquad (4.1)$$

And

$$v = \frac{53.35 + 85.58\gamma}{1 + \gamma} \cdot \frac{460 + t_e}{70.73\,p_e}\,. \qquad (4.2)$$

α was taken as unity in the calculations, v was found from equation (4.2), and H_w was measured by either a 12-inch micromonometer or a 48-inch water U-tube manometer, depending on flow rate. Coefficients K and Y_1 were obtained from reference (6). To obtain K the method of successive approximations was used, a rough estimate of the Reynolds number enabled a first approximation to be made, and with this value in conjunction with equations (4.1) and (4.2) a second and more accurate value of K was found. Generally two approximations were sufficient. For values not listed in reference (6) extrapolation with respect to 1/(Re) was used. Pulsations in the flow due to the blower were considered to have negligible effect on the air flow rate measurement.

The basic heat transfer procedure was the same for sound and no-sound runs. The heat transferred was determined by

$$Q_i = m_i\, h_{fg}, \qquad i = 1,2,3, \ldots, 21. \tag{4.3}$$

Since the first collection chamber started 0.38 inches downstream from the tube entrance, a correction was made for this section where experimental data were not available. The correction was made using Pohlhausen's solutions for a flat plate modified for a tube. Details of this applied correction are given in reference (2).

The condensate flow rates for each chamber, the air density, the air flow rate, the inlet air temperature, and the tube wall temperature were used to calculate the local temperature of the air in the tube corresponding to a total length from the inlet of the tube to the end of each chamber. The temperature difference from entrance to section i was determined by

$$\Delta t_i = \frac{\Sigma Q_i}{\dot{m} \cdot c_p}, \qquad i = 1,2,3, \ldots, 21. \tag{4.4}$$

The temperature of the air at section i was determined by

$$t_i = t_o + \Delta t_i, \qquad i = 1,2,3, \ldots, 21. \tag{4.5}$$

These local temperatures were employed with the inlet air and tube wall temperatures to calculate an average log-mean temperature. Basing the fluid properties on the tube wall temperature, which was almost the same as the steam temperature, the local heat transfer coefficient and Nusselt number were calculated for each collection chamber. Also the overall heat transfer coefficient and Nusselt number from the tube entrance to the end of each chamber were calculated.

$$h_{x_i} = \frac{Q_i}{A_{x_i}\ \Delta t_{am_i}}, \qquad i = 1,2,3, \ldots, 21. \quad (4.6)$$

$$h_{\ell m_i} = \frac{\Sigma Q_i}{A_i\ \Delta t_{\ell m_i}} \quad (4.7)$$

$$Nu_{x_i} = \frac{h_{x_i}\ D}{k} \quad (4.8)$$

$$Nu_{\ell m_i} = \frac{h_{\ell m_i}\ D}{k} \quad (4.9)$$

A program was written for a Burroughs 220 digital electronic computer to reduce the test data. Step by step details of the calculations made by the computer are given in the Appendix.

The Reynolds number was based on the air inlet temperature measured at the mixing chamber; since in the investigation only relative effects were of interest, no attempt was made to account for the drop in air temperature between the mixing chamber and the inlet plenum box. Subsequent tests showed this drop on the average to be less than 2.5 degrees Fahrenheit. Slight variations in the Reynolds number from run to run or during a run for a constant air flow rate were unavoidable because no heater was installed to keep the air inlet temperature constant. The air which was drawn from the laboratory was subject to ambient changes in temperature and pressure. However, this variation was relatively small, approximately between one and two per cent. The numerical results obtained for both sound and no-sound runs are given in tabulated form in the Appendix.

CHAPTER V

DISCUSSION OF RESULTS

General

Heat Transfer Without Sound.--Equations derived by Latzko (8) were used to determine theoretical heat transfer coefficients for various Reynolds numbers and distances along the test tube. The theoretical values appear to be an average 20 per cent less than the corresponding experimental values. Possibly the assumption made in calculating the experimental heat transfer, that the air inlet temperature is the same as the temperature in the mixing chamber, accounts partly for the discrepancy. It is interesting to note that experimental investigations by Boetler, Young, and Iverson (9) showed Latzko's equation to yield values low by two to eight per cent for $x/D = 5$ to 17.

Heat Transfer with Sound.--Experiments were conducted at a resonant frequency of 222.0 cps, which corresponded to the fourth harmonic for an open pipe. From an acoustical point of view the tube may be considered as long. The range of Reynolds numbers investigated was 16,100 to 200,000, and the maximum sound pressure level obtained was 164.5 decibels. Figs. 6 through 16 show the effect of increasing sound pressure level on the local Nusselt number for various lengths of tube. Only collection chambers 3 to 19 inclusive were plotted; values for chambers 1 and 2 were considered unreliable because of the possibility of acoustic streaming and the very high transfer rates occurring near the tube entrance. Flow in the region of chambers 20 and 21 was severely distorted by the horn and hence coefficients were of little significance.

At a Reynolds number of 16,100, it can be seen in Fig. 6 that the local Nusselt number oscillates about the no-sound values in a periodic manner. The period of the variation corresponds to the half wave length of the impressed resonant acoustic vibration, and the amplitude appears to be a function of the intensity of this parameter. The maximum values are at the velocity loops of the standing sound waves in the tube, and the minimum values at the velocity nodes. This same trend was noticed by Jackson _et al._ (2) and (3) for Reynolds numbers 2,100 and 11,600 and frequencies 221.0 cps and 216.0 cps, respectively. From Fig. 6 and Tables 1 and 2 it is apparent that there is no overall effect of resonant vibrations at a Reynolds number of 16,100 and frequency 222.0 cps, within the range of sound pressure levels tested.

A very different situation was observed at a Reynolds number of 43,500 and a frequency of 222.0 cps. Fig. 9 indicates that though the local Nusselt values still oscillate in a periodic manner, the maximum values are at the velocity nodes of the standing wave, instead of at the velocity loops. Furthermore, the effect of resonant vibrations is to suppress the heat transfer rate, and the degree of suppression appears to be a function of the sound pressure level. In reference to the average values, it is evident from Fig. 9 and the tables that the average values are considerably lower with sound than without.

For Reynolds numbers of 52,000, 61,500, 75,500, 81,500 and a frequency of 222.0 cps, the same effects that were noted for a Reynolds number of 43,500 are apparent. Figs. 10 through 13 show that the effect of sound is still to suppress the heat transfer rate. The only notable tendency appears to be the increase of the critical or threshold sound pressure level with increasing Reynolds number. For instance consider collection chamber 7, at a Reynolds number of 43,500 and SPL of 163.4 decibels, the decrease in the no-sound local Nusselt number due to this acoustic intensity was 19 per cent. At a Reynolds number of 75,500 and SPL of 163.6 decibels, the decrease was only 10.8 per cent. Tests conducted at a Reynolds number of 91,500 showed only a slight depression in the local Nusselt numbers at the highest sound pressure level obtained, namely 162.9 decibels. At higher Reynolds numbers, for instance 135,000 and 203,000, no measurable effect of sound on the heat transfer coefficient could be determined, with the frequency and sound pressure levels tested (Figs. 15 and 16).

For some values of Reynolds number in between 16,100 and 43,500, coinciding with the change of phase in the periodic oscillations of the local heat transfer coefficients, the effects of resonant vibrations would be expected to be comparatively small. Tests conducted at values of Reynolds numbers around 22,500 and 30,000 showed this tendency to a certain extent. Fig. 7 illustrates graphically that at a Reynolds number of 22,500 and a frequency of 222.0 cps, the effect of resonant vibrations on the local heat transfer coefficients is small and the periodic effect does not appear to be very pronounced.

Critical Sound Pressure Levels

Critical or the threshold sound pressure levels were obtained for each Reynolds number tested, by plotting maximum sound pressure levels in the test section versus the difference between the local Nusselt number with sound to that for no sound. It was found that a fairly consistent set of critical values was obtained by plotting values for several chambers and extrapolating to zero effect. Fig. 17 illustrates graphically how the critical sound pressure level value for a Reynolds number of 61,500 was found. It is interesting to note the straight line relationship between local Nusselt number and supercritical sound pressure levels. This characteristic was evident with all the Reynolds numbers and sound pressure levels tested. For the sake of accuracy only chambers showing the greater effects, namely the maxima and minima, were plotted. Critical sound pressure level values were found for Reynolds numbers up to and including 75,500. For Reynolds numbers of 81,000 and 91,500 the comparatively small effects obtained with the sound pressure levels tested made an estimation of the critical value highly inaccurate. The values obtained and two found by Jackson, et al. (3) with the same test section are shown in Fig. 18 plotted versus Reynolds number and mean air velocity through the test section. Two distinct regimes are apparent and in each one the critical sound pressure level is directly proportional to the Reynolds number. It appears that some sort of transition from one type of heat transfer mechanism to another occurs at approximately a Reynolds number of 35,000. If the curve in Fig. 18 can be extrapolated to Reynolds numbers of 91,500, 135,000, and 203,000, then at a frequency of 222.0 cps one would expect critical sound pressure level values of 161.6, 171.0, and 182.0 decibels, respectively. The experimental results indicate only slight effects at a Reynolds number of 91,500 and a sound pressure level of 162.9 decibels. At Reynolds numbers 135,000 and

203,000 no effects were evident with the highest sound pressure levels tested (162.7 and 161.4 decibels, respectively).

Fig 19 shows a rather interesting plot, which may help shed light on the heat transfer mechanism taking place. The dimensionless quantity $(u_{max} - V_o)/V_o$ is plotted versus Reynolds number. The value of u_{max} was determined from the definition of sound pressure level and the solution to the equation of motion for a plane sound wave.

The two equations are:

$$P_{max} = 2.955 \cdot 10^{\frac{SPL_{crit} - 134}{20}} \tag{5.1}$$

$$u_{max} = \frac{P_{max}}{\sqrt{\frac{kp\rho}{g}}} \tag{5.2}$$

In equation (3) the critical sound pressure level was used. It is interesting to note that $u_{max} = \overline{V}_o$ at a Reynolds number of 22,000; this is near the value that the experimental results point to as marking the change from the resonant vibrations increasing the local transfer coefficient, to suppressing the coefficient. The two distinct regimes are still evident in Fig. 19.

No physical explanation is available at this time to describe the phenomena taking place. However, it seems feasible to suppose that in each regime quite different heat transfer mechanisms are involved, and in the transition region these mechanisms tend to counteract each other. Experimental results appear to support this view; the effects of resonant acoustic vibrations on heat transfer rates are small in the transition region.

It must be emphasized that in this discussion attention has been confined to the effects of plane longitudinal sound waves, and it is probable that the effects of radial and transverse vibrations would be substantially different. As stated in the introduction, no attempt has been made to formulate an analytical solution.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions.--Reasonable agreement was found to exist between the theoretically calculated and the experimental heat transfer coefficients for runs without sound. This fact gave evidence of the reliability of the data. No such comparison was possible in the case of runs with sound.

Runs with sound were confined to plane longitudinal waves and to a single resonant frequency. With the possible exception of certain values of Reynolds number in the vicinity of 35,000, critical sound pressure levels were found to exist for values of Reynolds number up to at least 76,000. These critical values appear to fall into two distinct regimes depending on the Reynolds number (Fig. 18), and in each regime the critical sound pressure level is directly proportional to the Reynolds number. The existence of a transition region where the effects of supercritical acoustic vibrations are relatively small, and the different effects in each regime of resonant vibrations on heat transfer rates, including a shift in phase of the periodic oscillations, suggests that different heat transfer mechanisms are involved in each regime.

Recommendations.--Additional experimental data and theoretical work will be required before the heat transfer processes involved are understood. It is recommended that experiments into the effects of radial and transverse vibrations be conducted, and also an investigation into the effects of frequency on critical sound pressure levels.

APPENDIX A

CALCULATION OF COEFFICIENTS

The program for the Burroughs 220 digital electronic computer was written by Mr. K. R. Purdy. Only part of the program related to the coefficients used in the report is outlined below.

Input Data: t_s, t_o, τ, V_a, p, p_o, h_{fg},* γ, V_i ____(Test Data).

Run Number, Sound or No-Sound, SPL, Frequency ________

(Data for designation, not involved in computations).

D, A_i, A_{x_i}, x_i ______(Apparatus design data, see Table 3).

Computations:

$$v = \frac{53.35 + 85.58\gamma}{1 + \gamma} \cdot \frac{t_{db} + 460}{70.73p}$$

$$c_p = \frac{0.240 + 0.446\gamma}{1 + \gamma}$$

$$\dot{m} = \frac{3600\ V_a}{\tau \cdot v}$$

$$\mu = 0.0407 + 0.0000562\ t_o^{**}$$

---

* From Reference (10) at t_s.

**Equations obtained from data in Table A-2, Reference (11).

Computations (Continued)

$$Re = \frac{4\mathring{m}}{\pi \; D \; \mu}$$

$$m_i = \frac{V_i}{\tau}$$

Heat transferred:

$$Q_i = m_i \cdot h_{fg}$$

$$k = 0.0132 + 0.000025 \; t_s{*}$$

A correction was made to account for the first 0.38 inches of heat transfer surface where no condensate was collected. Details of the correction are given in reference (2).

$$Q_{oa} = 0.1869 \; k_{oa}(Re)^{\frac{1}{2}} \; (t_s - t_o)$$

$$Q_1 \; (\text{corrected}) = Q_1 + Q_{oa}$$

Total heat transferred from entrance to section i,

$$\Sigma Q_1 = Q_1(\text{corrected}) + Q_2 + \cdots + Q_i$$

Temperature difference from entrance to section i,

$$\Delta \; t_i = \frac{\Sigma Q_i}{\mathring{m} \cdot c_p}$$

---

*Equations obtained from data in Table A-2, Reference (11).

Temperature of air at section i,

$$t_i = t_o + \Delta t_i$$

Logarithmic mean temperature difference,

$$\Delta t_{\ell m_i} = \frac{-\Delta t_i}{\log_e \frac{t_s - t_i}{t_s - t_o}}$$

Average heat transfer coefficient,

$$h_{\ell m_i} = \frac{\Sigma Q_i}{A_i \Delta t_{\ell m_i}}$$

Average Nusselt number, properties based on tube wall temperature,

$$Nu_{\ell m_i} = \frac{h_{\ell m_i} D}{k_x}$$

Local heat transfer coefficient,

$$h_{x_i} = \frac{Q_i}{A_{x_i} \Delta t_{am_i}}$$

where, $$\Delta t_{am_i} = \frac{(t_s - t_{i-1}) + (t_s - t_i)}{2}$$

Local Nusselt number,

$$Nu_{x_i} = \frac{h_{x_i} D}{k_x}$$

Output Data:

Run Number, Sound or No-Sound, SPL, Frequency (Data for Designation).

h_{x_i}, Nu_{x_i}, Re (Local Data).

t_i, $h_{\ell m_i}$, $Nu_{\ell m_i}$ (Average Data).

APPENDIX B

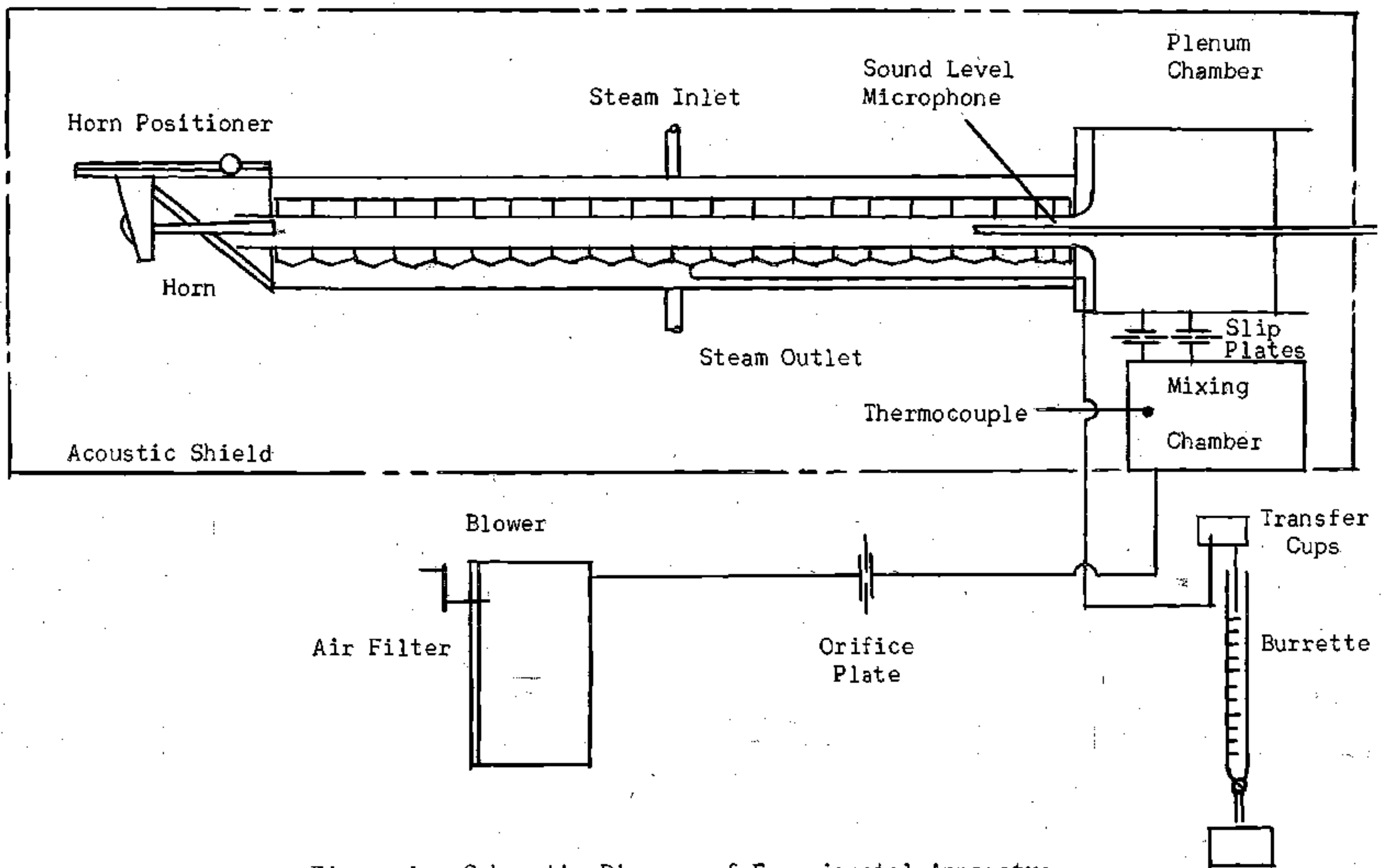

Figure 1. Schematic Diagram of Experimental Apparatus

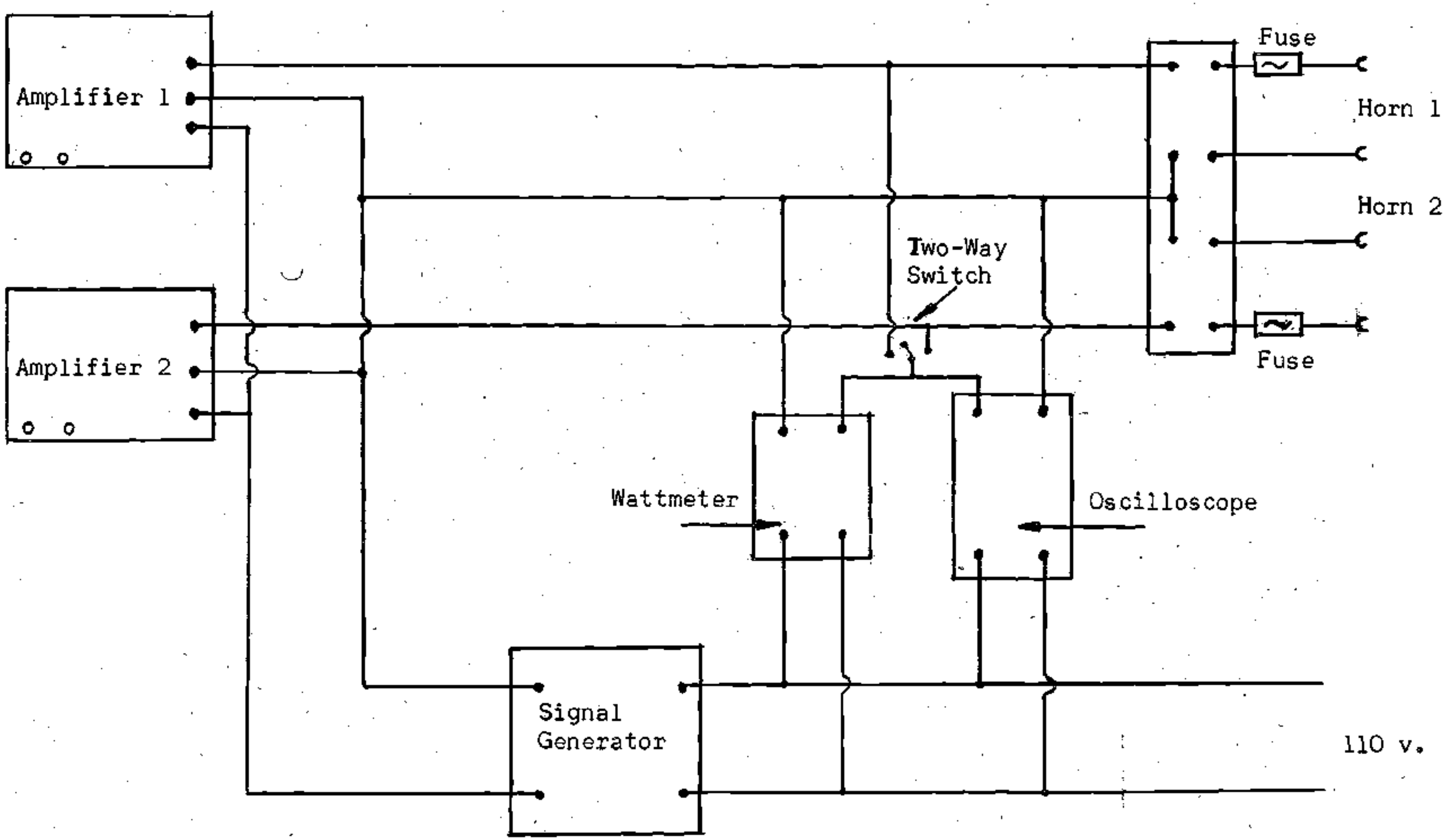

Figure 2. Schematic Diagram of Sound Generating Equipment

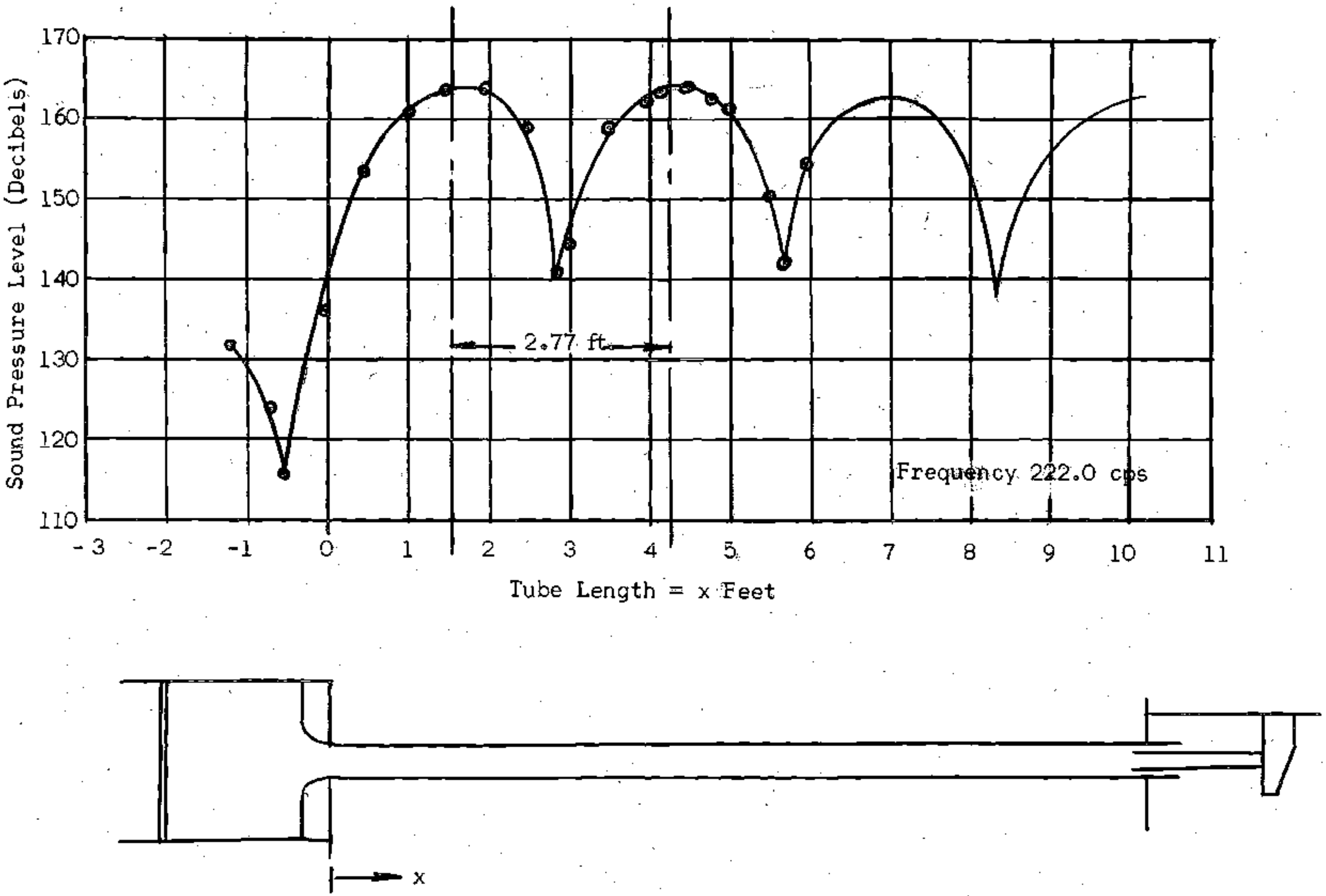

Figure 3. Sound Pressure Level Measured Along Axis of Tube

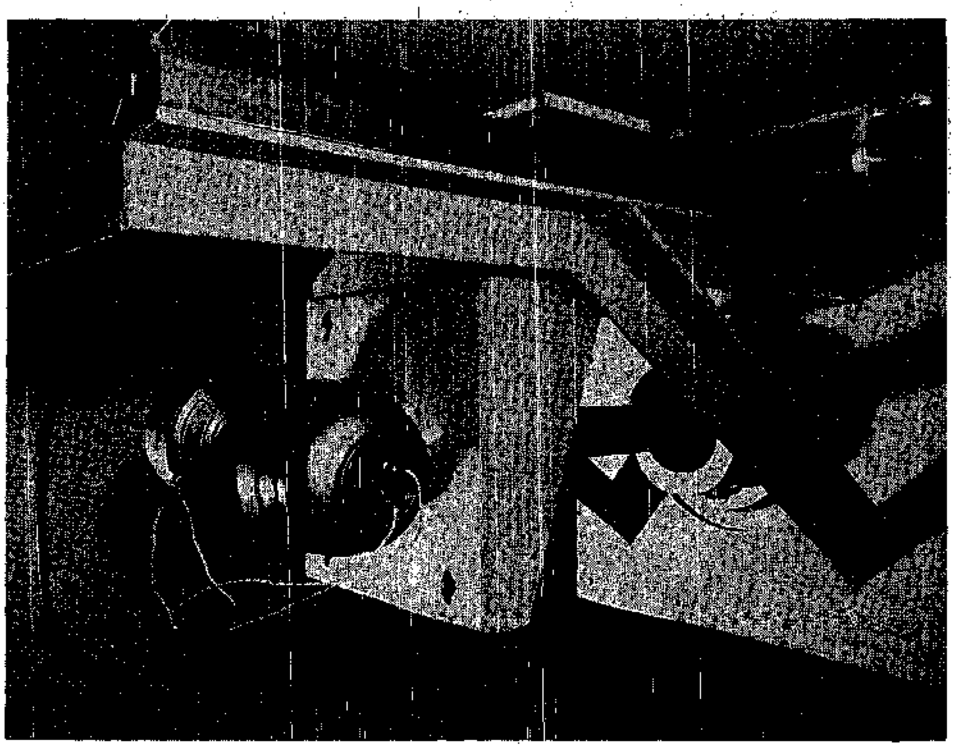

Figure 4. Exit Section with Two Drivers

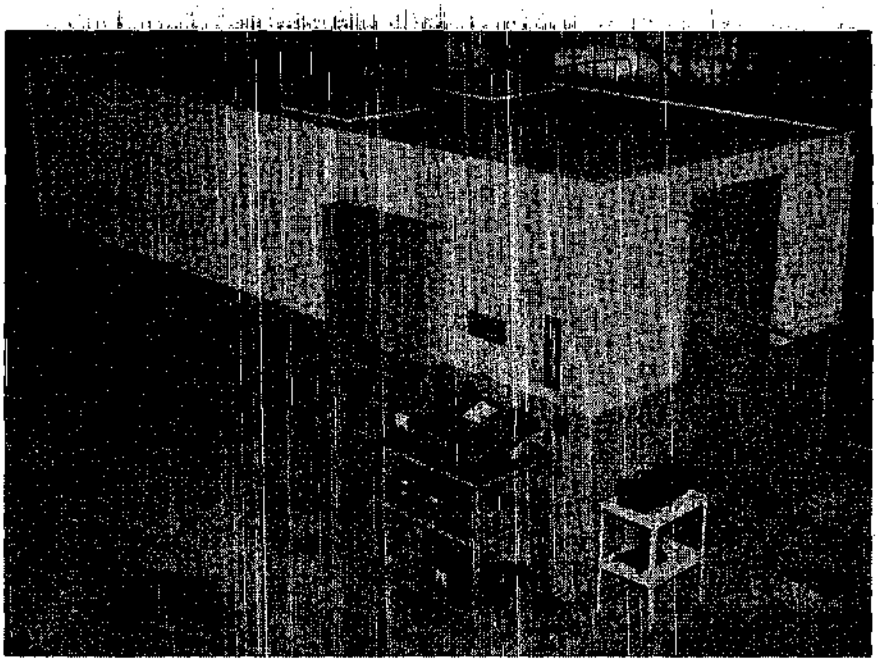

Figure 5. Acoustic Shield and External Sound Generating and Measuring Equipment

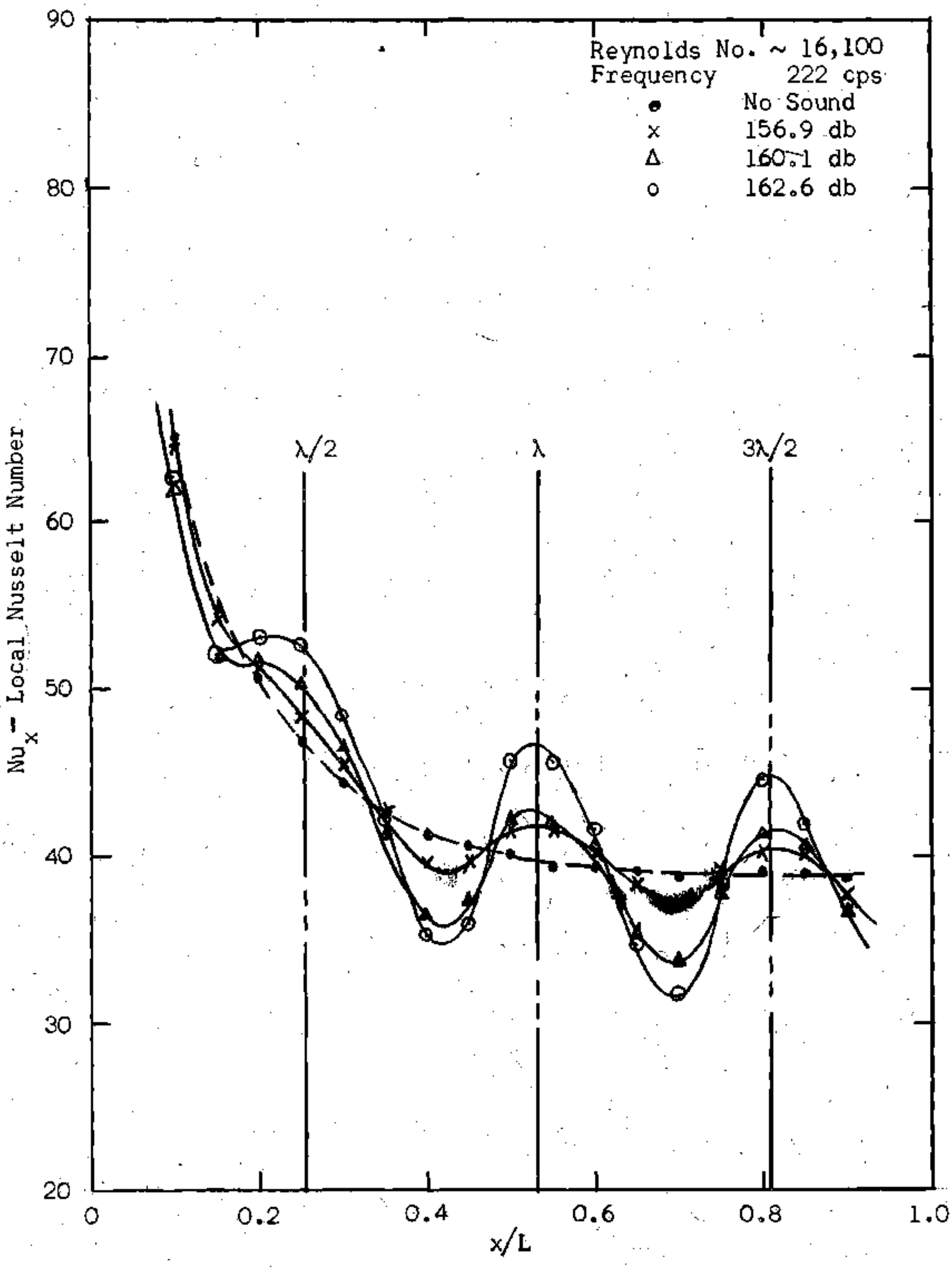

Figure 6. Local Nusselt Number Versus x/L

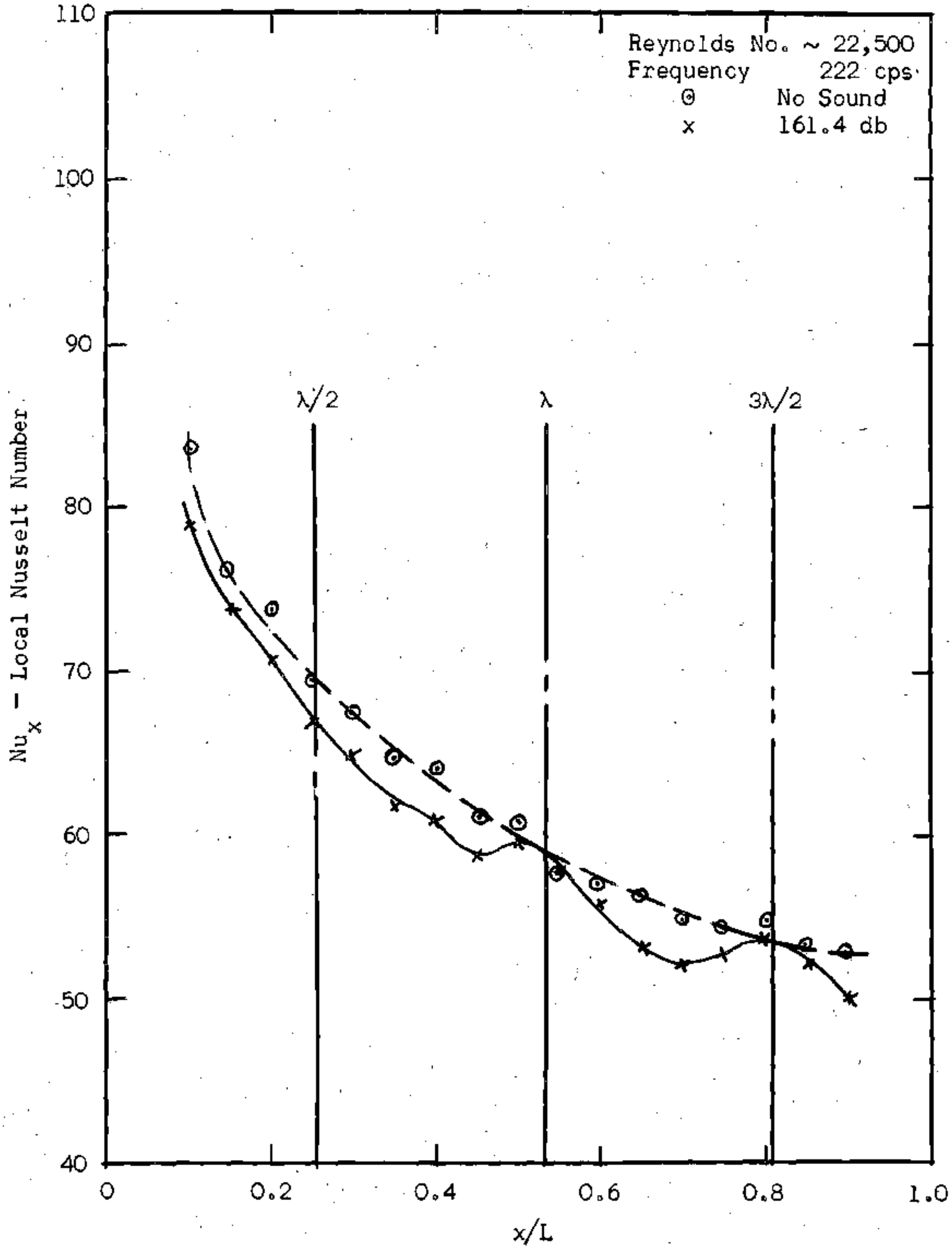

Figure 7. Local Nusselt Number Versus x/L

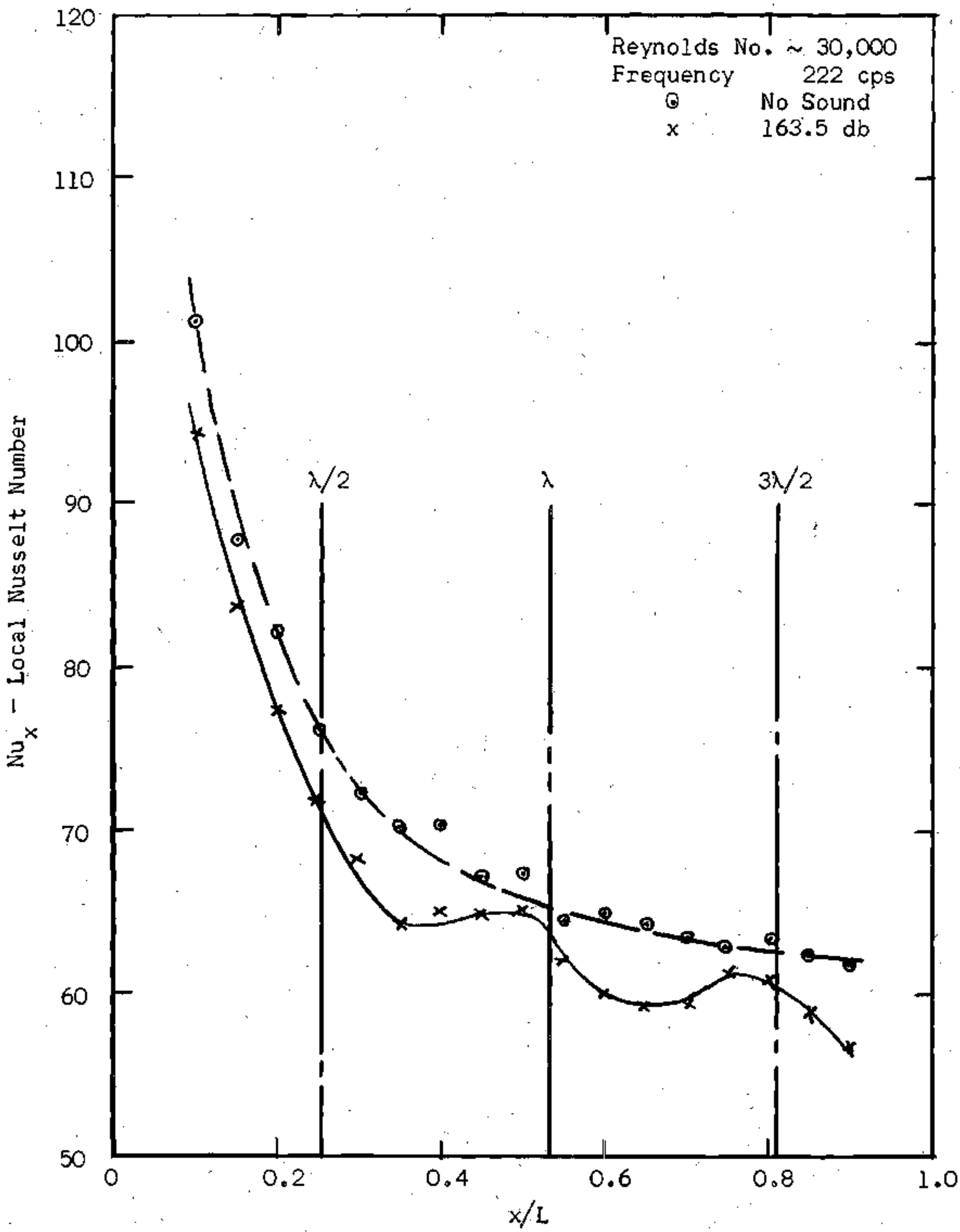

Figure 8. Local Nusselt Number Versus x/L

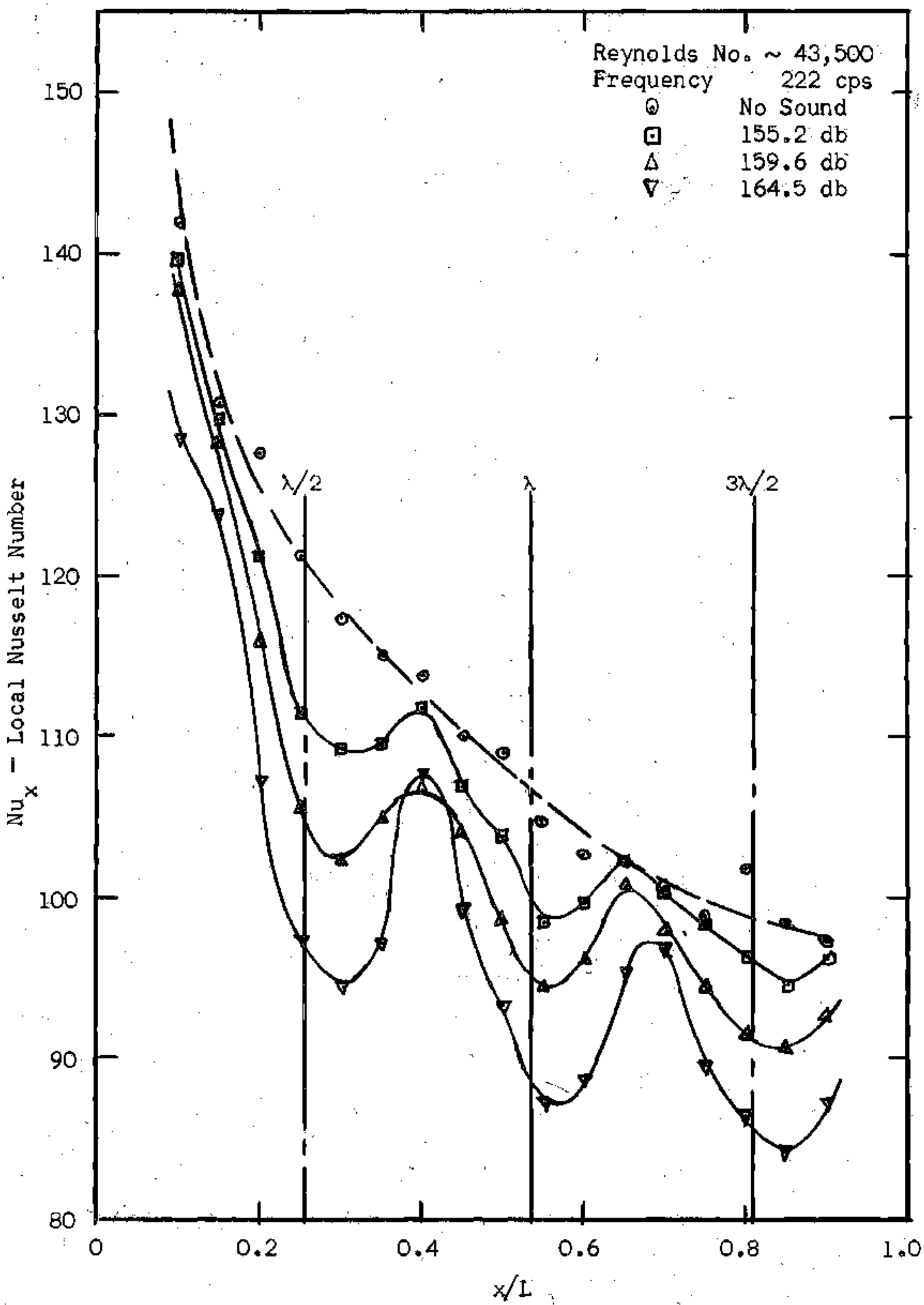

Figure 9. Local Nusselt Number Versus x/L

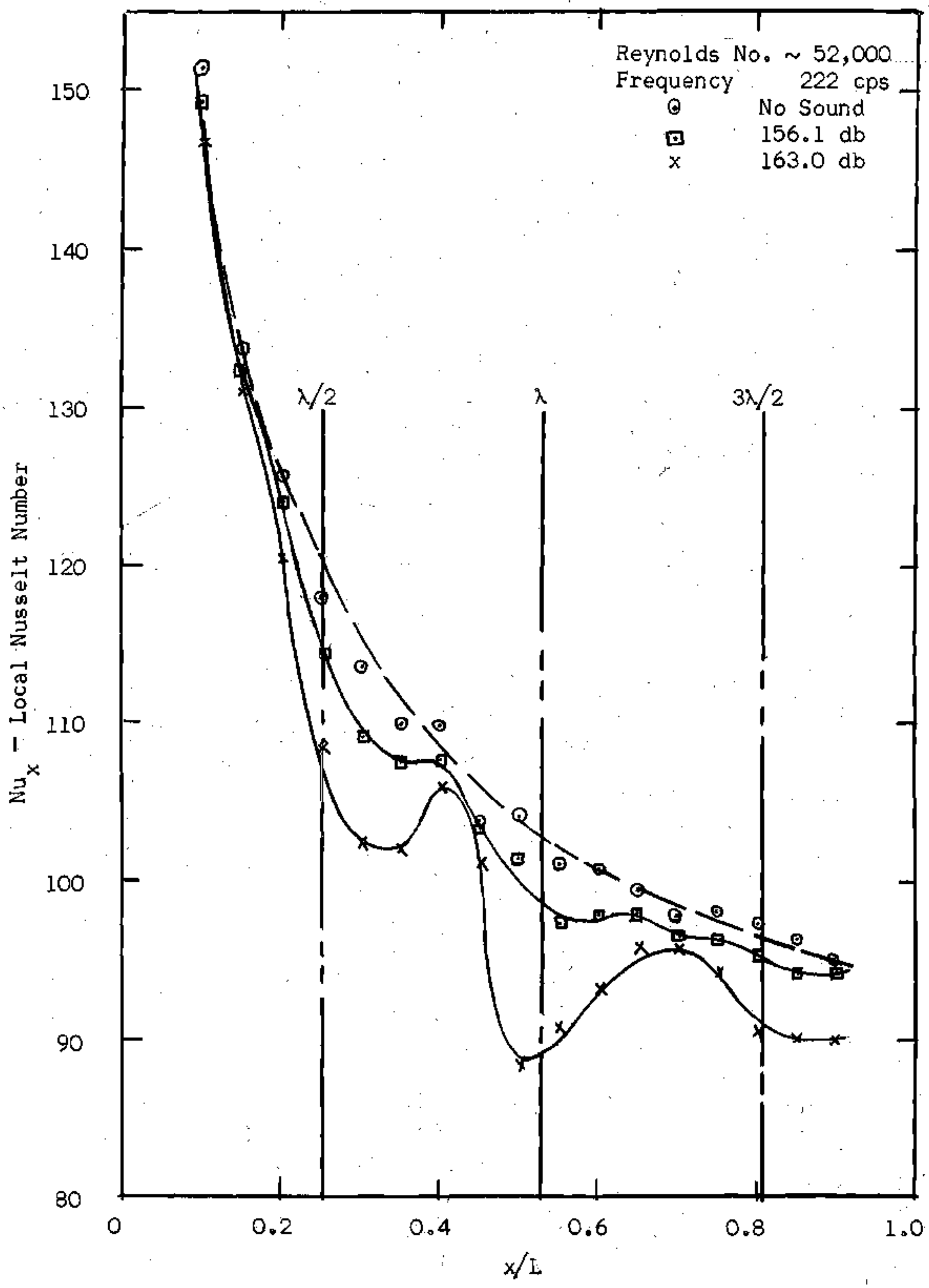

Figure 10. Local Nusselt Number Versus x/L

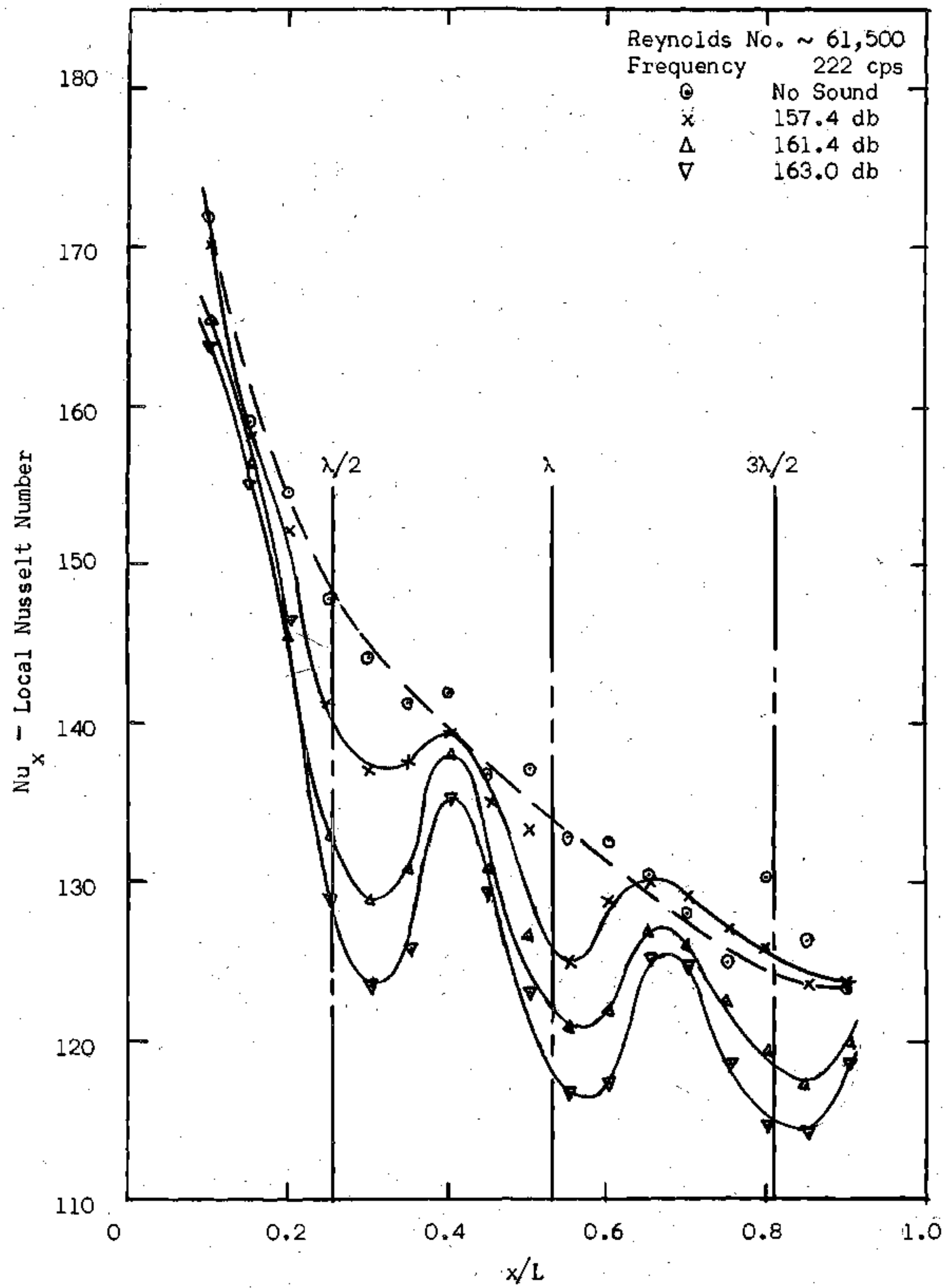

Figure 11. Local Nusselt Number Versus x/L

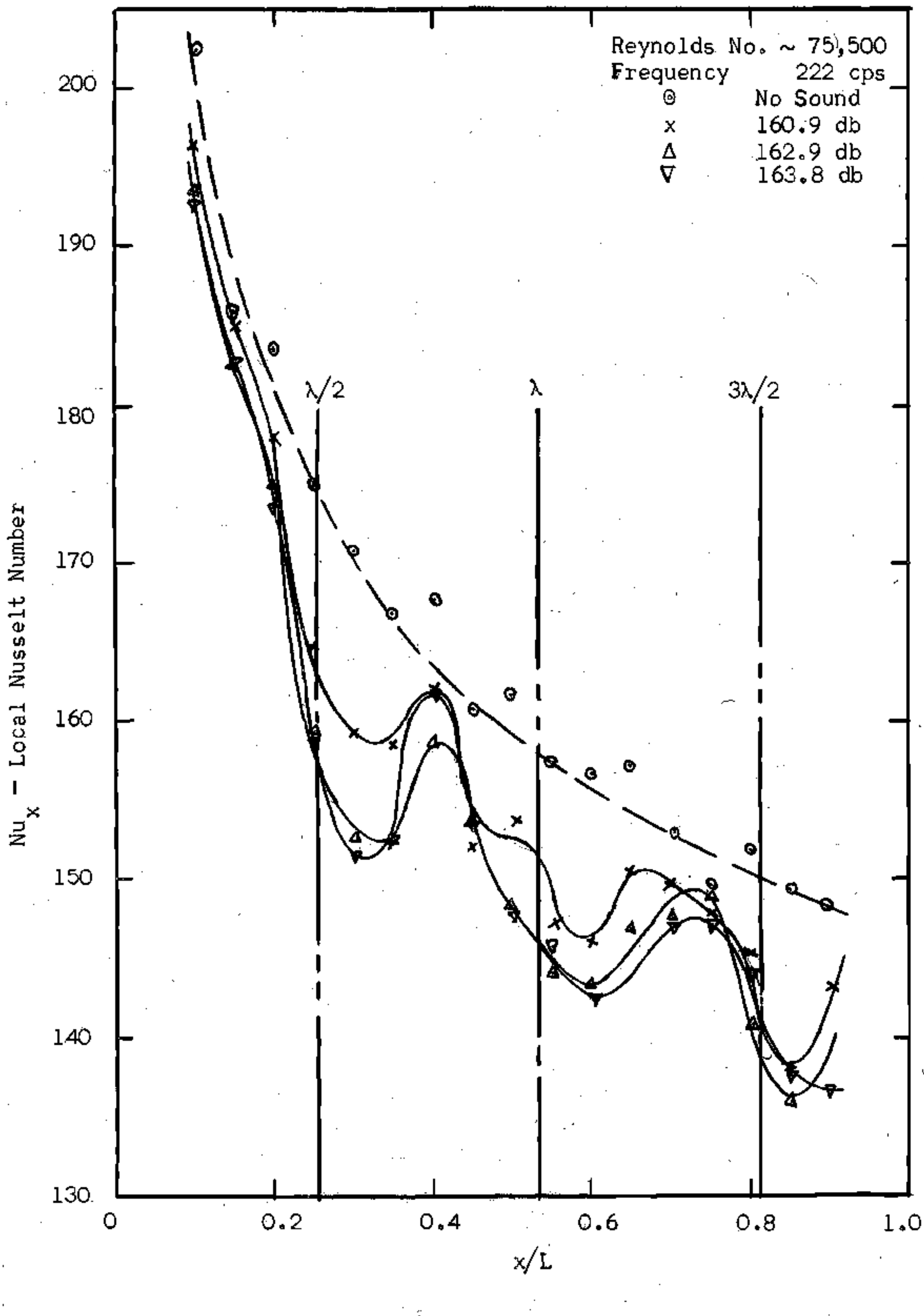

Figure 12. Local Nusselt Number Versus x/L

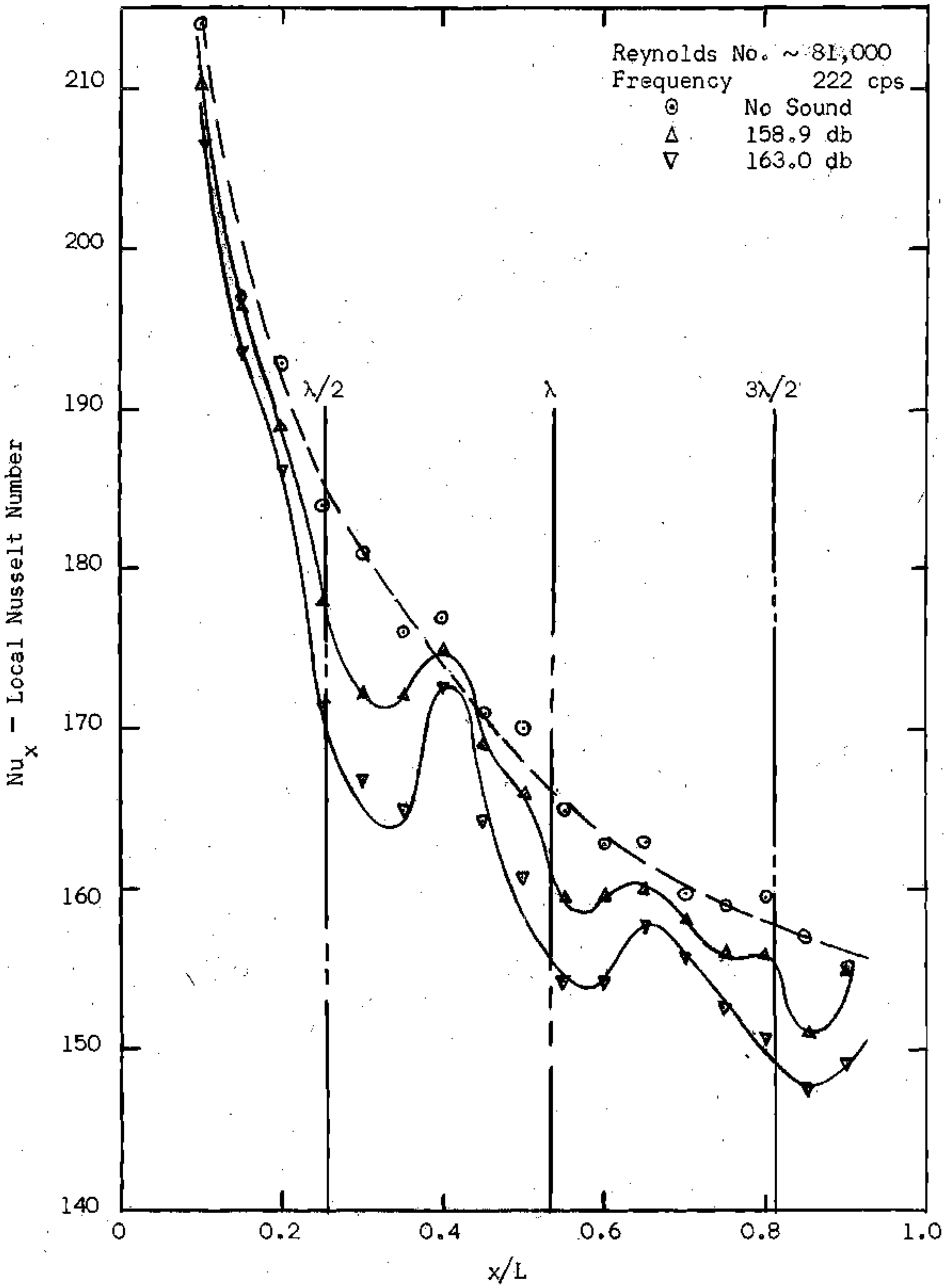

Figure 13. Local Nusselt Number Versus x/L

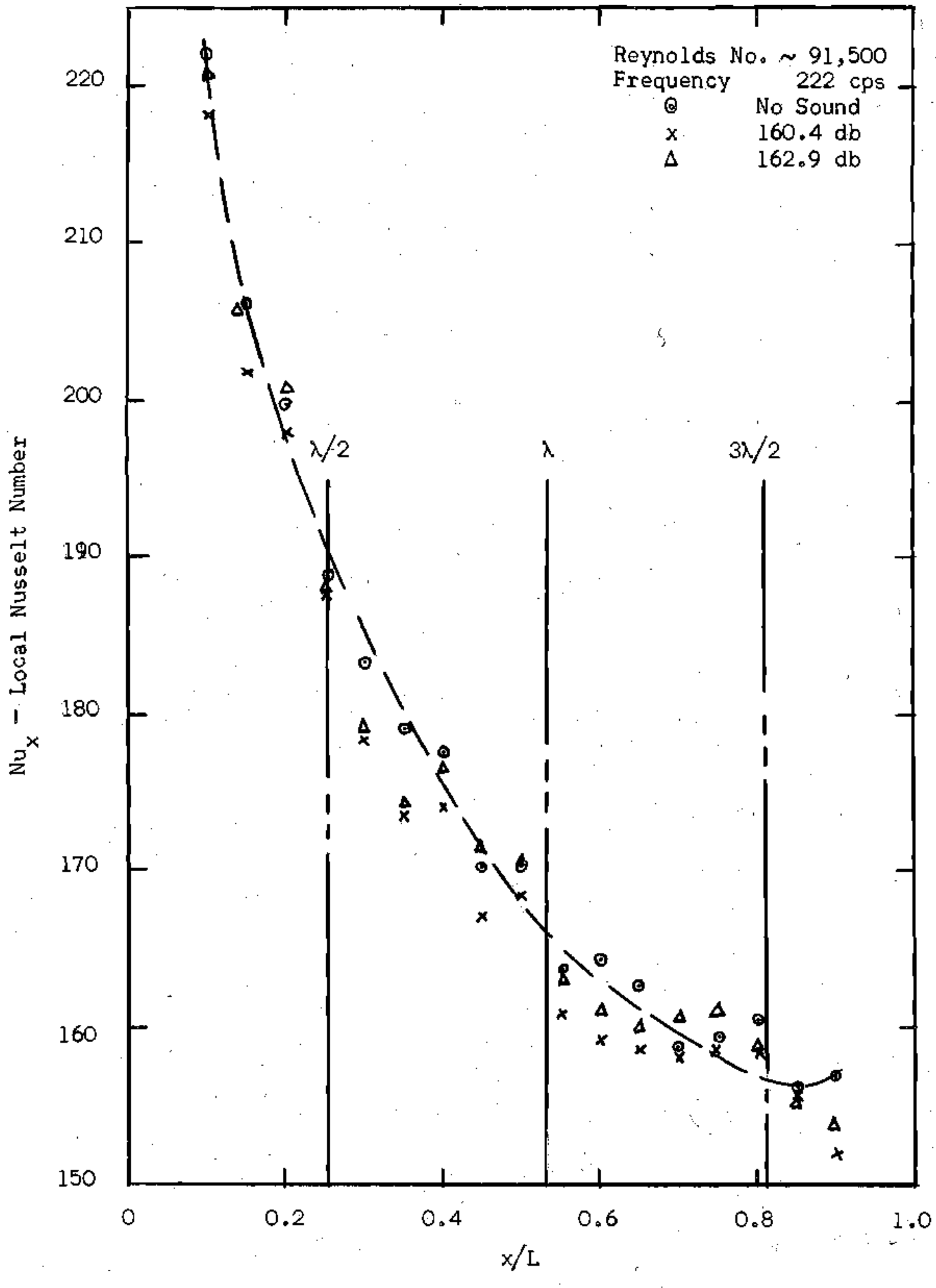

Figure 14. Local Nusselt Number Versus x/L

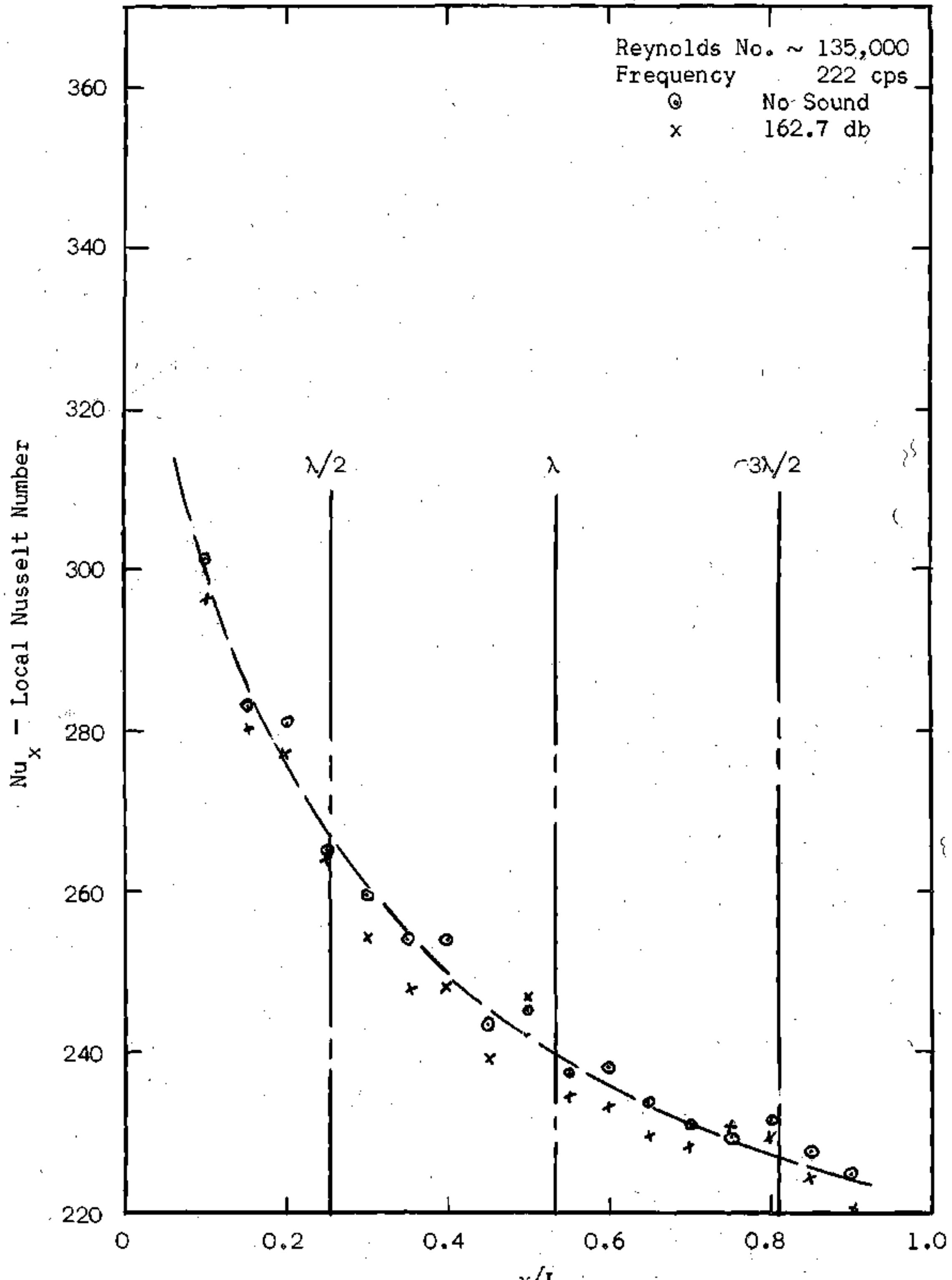

Figure 15. Local Nusselt Number Versus x/L

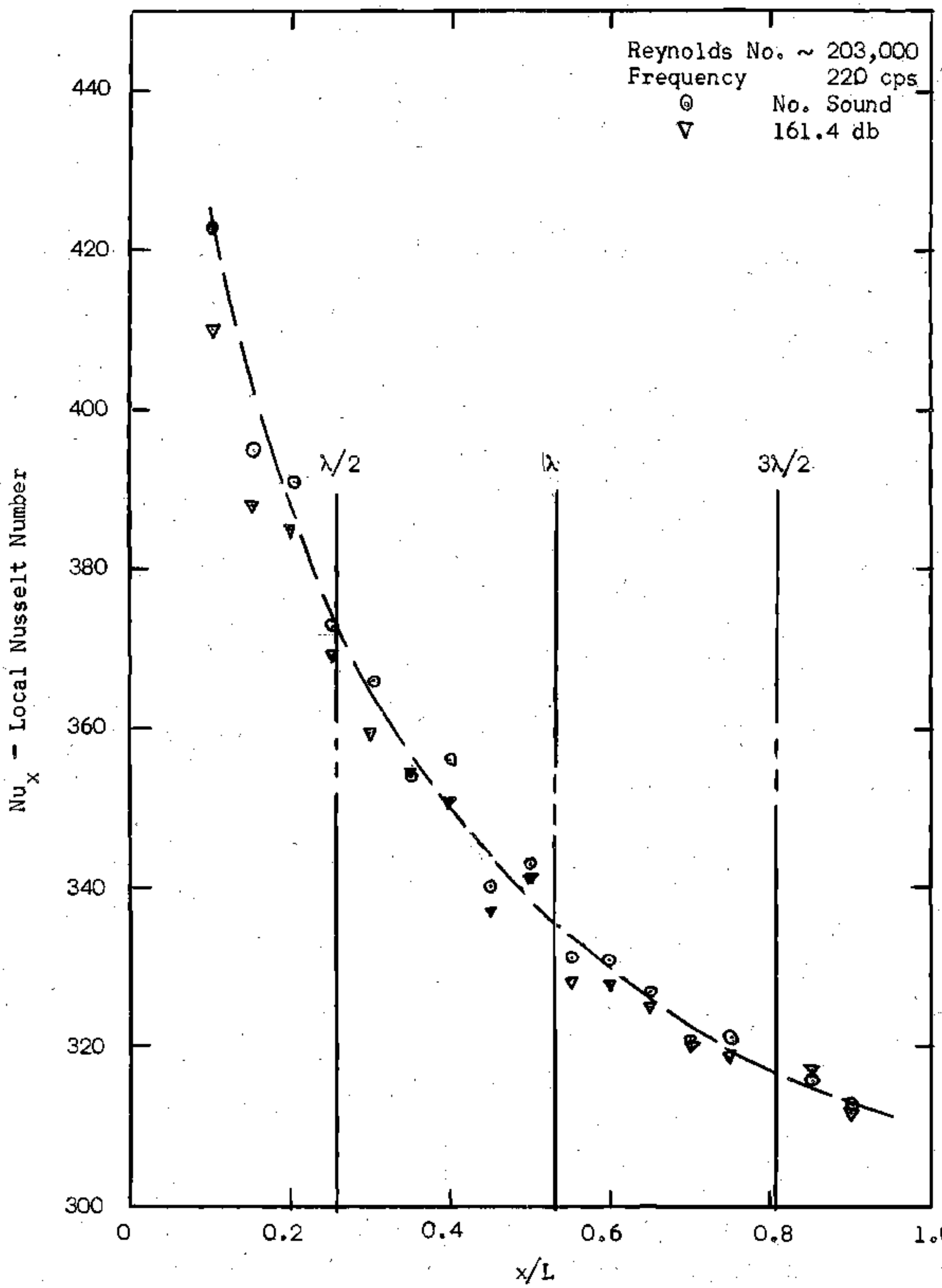

Figure 16. Local Nusselt Number Versus x/L

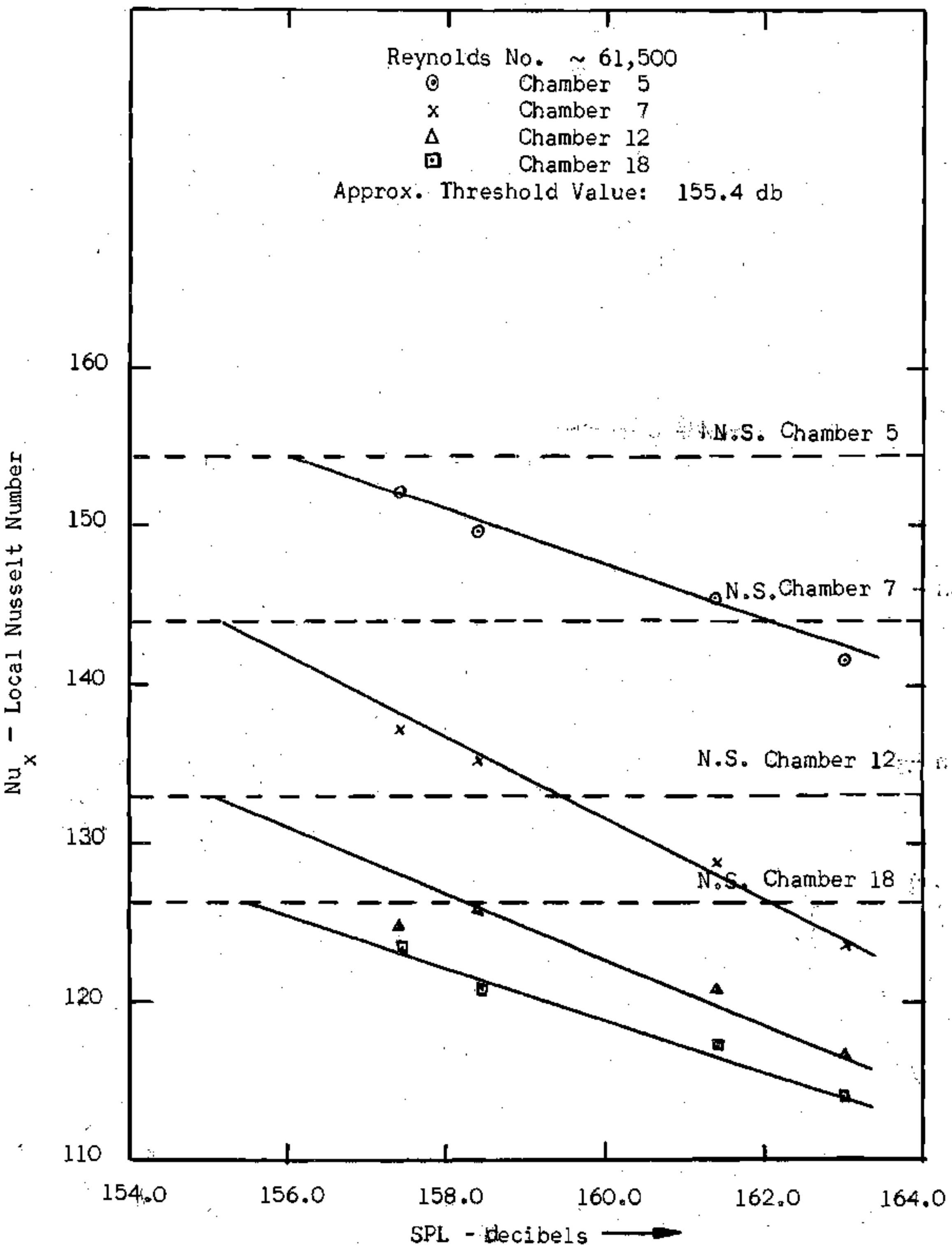

Figure 17. Local Nusselt Number Versus SPL for Various Collection Chambers

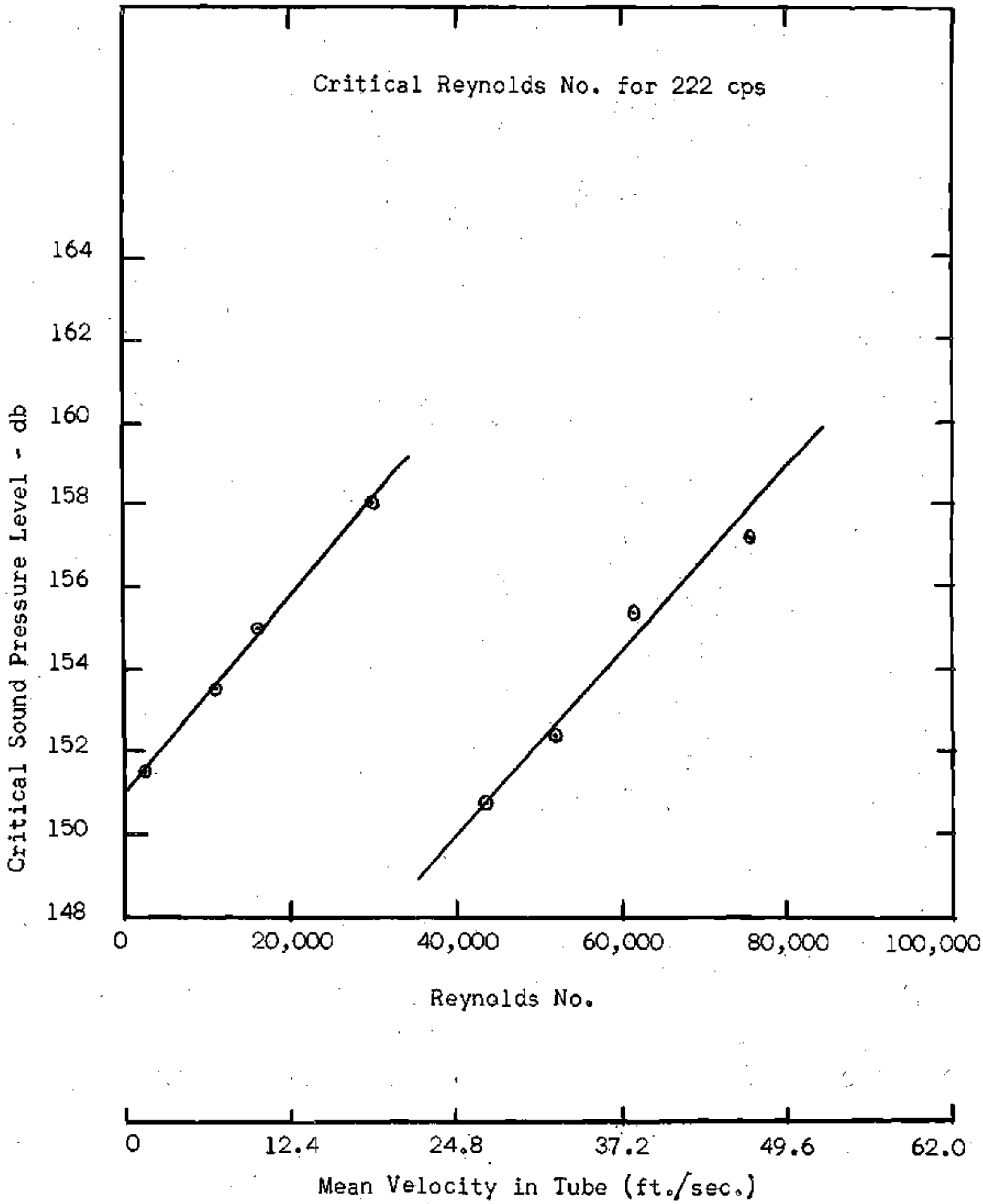

Figure 18. Critical Sound Pressure Versus Reynolds Number

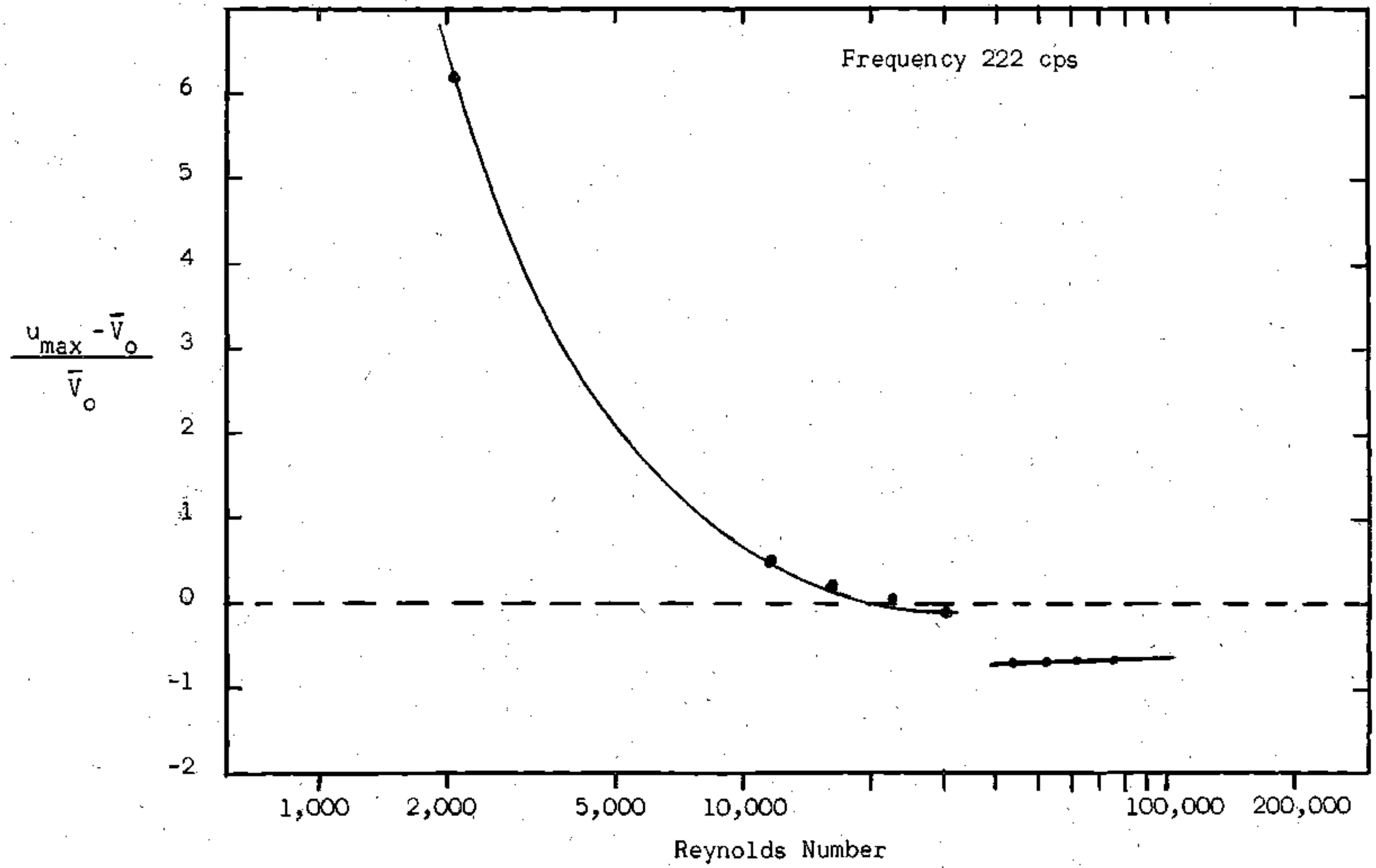

Figure 19. Reynolds Number Versus $\frac{u_{max} - \bar{V}_o}{\bar{V}_o}$

APPENDIX C

Table 1. Summary Tabulation of No-Sound Data

Reynolds Number = 15966.5 t_o = 120.90 F t_s 211.10 F

Chamber Number	t	Local Data		Average Data	
		h_x	Nu_x	h_{lm}	Nu_{lm}
1	126.27	10.134	177.98	10.137	178.04
2	129.98	8.3354	146.39	9.1992	161.56
3	133.14	3.6950	64.895	6.5109	114.35
4	135.75	3.1271	54.921	5.3853	94.581
5	138.05	2.8937	50.822	4.7662	83.709
6	140.12	2.6699	46.892	4.3475	76.355
7	142.03	2.5234	44.319	4.0414	70.979
8	143.85	2.4457	42.955	3.8098	66.910
9	145.52	2.3707	41.636	3.6305	63.763
10	147.18	2.3123	40.610	3.4787	61.096
11	148.73	2.2956	40.317	3.3595	59.004
12	150.22	2.2421	39.377	3.2564	57.192
13	151.69	2.2574	39.646	3.1713	55.697
14	153.11	2.2292	39.152	3.0970	54.392
15	154.48	2.2034	38.698	3.0315	53.241
16	155.80	2.1946	38.544	2.9746	52.242
17	157.12	2.2242	39.063	2.9264	51.396
18	158.40	2.2162	38.923	2.8831	50.636
19	159.64	2.1921	38.500	2.8433	49.937
20	161.00	2.4560	43.135	2.8216	49.555
21	162.40	2.6286	46.167	2.8105	49.361

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 22520.9 t_o = 109.80 F t_s = 211.04 F

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	114.94	11.961	210.08	11.964	210.13
2	118.68	10.258	180.16	11.052	194.11
3	122.02	4.7590	83.581	7.9759	140.07
4	124.99	4.3331	76.102	6.7607	118.73
5	127.75	4.2053	73.858	6.1226	107.53
6	130.27	3.9669	69.671	5.6894	99.923
7	132.65	3.8473	67.570	5.3780	94.453
8	134.88	3.6922	64.846	5.1316	90.125
9	136.98	3.6523	64.145	4.9457	86.861
10	139.01	3.4747	61.027	4.7752	83.867
11	140.91	3.4701	60.945	4.6428	81.541
12	142.68	3.2895	57.774	4.5173	79.338
13	144.39	3.2499	57.077	4.4089	77.434
14	146.05	3.2226	56.599	4.3151	75.786
15	147.62	3.1279	54.935	4.2279	74.254
16	149.13	3.1081	54.588	4.1516	72.914
17	150.62	3.1384	55.120	4.0865	71.770
18	152.05	3.0451	53.481	4.0232	70.658
19	153.42	3.0157	52.965	3.9653	69.642
20	154.88	3.2811	57.625	3.9274	68.977
21	156.41	3.5357	62.097	3.9059	68.600

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 29957.9 t_o = 118.30 F t_s = 211.28 F

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	122.78	15.262	268.04	15.265	268.10
2	126.03	13.025	228.76	14.072	247.15
3	128.81	5.7774	101.46	10.019	175.97
4	131.18	5.0060	87.921	8.3507	146.66
5	133.31	4.6854	82.289	7.4389	130.64
6	135.23	4.3463	76.334	6.8203	119.78
7	137.03	4.1269	72.480	6.3676	111.83
8	138.74	4.0021	70.288	6.0236	105.79
9	140.37	4.0127	70.474	5.7722	101.37
10	141.96	3.8280	67.231	5.5478	97.435
11	143.47	3.8431	67.497	5.3755	94.410
12	144.90	3.6736	64.519	5.2182	91.647
13	146.31	3.7048	65.068	5.0889	89.376
14	147.67	3.6645	64.360	4.9764	87.400
15	149.00	3.6169	63.524	4.8765	85.645
16	150.27	3.5782	62.843	4.7881	84.093
17	151.52	3.6100	63.403	4.7124	82.763
18	152.74	3.5497	62.343	4.6416	81.520
19	153.93	3.5277	61.957	4.5775	80.394
20	155.25	4.0155	70.524	4.5456	79.834
21	156.83	4.9719	86.794	4.5627	80.135

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 43781.4 t_o = 121.00 F t_s = 210.52 F

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	124.83	19.804	347.81	19.807	347.87
2	127.74	17.612	309.33	18.590	326.50
3	130.32	8.0832	141.96	13.453	236.27
4	132.66	7.4442	130.74	11.447	201.05
5	134.85	7.2775	127.81	10.405	182.74
6	136.87	6.9046	121.26	9.7007	170.37
7	138.78	6.6836	117.38	9.1899	161.40
8	140.63	6.5510	115.05	8.8030	154.60
9	142.36	6.4887	113.96	8.5112	149.48
10	144.07	6.2625	109.98	8.2494	144.88
11	145.66	6.2109	109.08	8.0417	141.23
12	147.17	5.9689	104.83	7.8486	137.84
13	148.62	5.8540	102.81	7.6774	134.83
14	150.04	5.8513	102.76	7.5322	132.28
15	151.39	5.7322	100.67	7.3992	129.95
16	152.69	5.6242	98.777	7.2778	127.81
17	154.00	5.8228	102.26	7.1834	126.16
18	155.24	5.6136	98.591	7.0873	124.47
19	156.44	5.5361	97.230	6.9976	122.89
20	157.69	5.8913	103.46	6.9360	121.81
21	159.15	7.0686	124.14	6.9388	121.86

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 52465.1 t_o = 115.00 F t_s = 210.56 F

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{1m}	Nu_{1m}
1	118.79	21.775	382.44	21.778	382.49
2	121.63	19.030	334.22	20.284	356.25
3	124.09	8.5019	149.31	14.526	255.12
4	126.24	7.5145	131.97	12.190	214.09
5	128.20	7.1388	125.37	10.931	191.99
6	129.97	6.5711	115.40	10.058	176.65
7	131.66	6.3564	111.63	9.4350	165.70
8	133.26	6.1469	107.95	8.9560	157.29
9	134.78	6.0684	106.57	8.5946	150.94
10	136.27	5.8406	102.57	8.2762	145.35
11	137.61	5.5094	96.760	7.9974	140.45
12	138.95	5.6149	98.614	7.7767	136.58
13	140.28	5.6016	98.380	7.5906	133.31
14	141.58	5.6276	98.837	7.4351	130.58
15	142.83	5.4465	95.657	7.2888	128.01
16	144.03	5.3999	94.838	7.1600	125.75
17	145.22	5.4596	95.887	7.0506	123.82
18	146.39	5.3863	94.599	6.9491	122.04
19	147.45	4.9773	87.416	6.8363	120.06
20	148.65	5.7686	101.31	6.7768	119.02
21	149.98	6.5169	114.43	6.7603	118.73

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 62049.7 t_o = 127.00 F t_s = 210.88 F

Chamber Number	t	Local Data		Average Data	
		h_x	Nu_x	h_{lm}	Nu_{lm}
1	129.98	23.296	409.14	23.298	409.19
2	132.26	20.793	365.19	21.902	384.67
3	134.35	9.7767	171.70	15.971	280.50
4	136.26	9.0580	159.08	13.662	239.94
5	138.05	8.7943	154.45	12.444	218.55
6	139.72	8.4119	147.73	11.631	204.29
7	141.32	8.1979	143.97	11.049	194.06
8	142.87	8.0490	141.36	10.608	186.31
9	144.35	8.0848	141.99	10.289	180.70
10	145.80	7.7789	136.62	9.9958	175.55
11	147.19	7.8176	137.29	9.7726	171.63
12	148.51	7.5625	132.81	9.5656	168.00
13	149.80	7.5456	132.52	9.3908	164.92
14	151.05	7.4214	130.34	9.2332	162.16
15	152.26	7.2948	128.11	9.0891	159.63
16	153.40	7.1191	125.03	8.9538	157.25
17	154.57	7.4201	130.31	8.8534	155.49
18	155.68	7.1886	126.25	8.7507	153.68
19	156.75	7.0201	123.29	8.6501	151.92
20	157.89	7.6252	133.92	8.5919	150.89
21	159.26	9.4327	165.66	8.6287	151.54

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 75402.5 t_o = 124.00 F t_s = 210.40 F

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	126.95	27.106	476.06	27.109	476.11
2	129.21	24.250	425.91	25.510	448.04
3	131.31	11.530	202.50	18.671	327.91
4	133.22	10.591	186.02	15.972	280.51
5	135.03	10.461	183.73	14.592	256.28
6	136.72	9.9714	175.12	13.660	239.92
7	138.34	9.7280	170.85	12.993	228.19
8	139.90	9.5033	166.90	12.480	219.18
9	141.40	9.5480	167.69	12.108	212.66
10	142.86	9.1451	160.61	11.762	206.58
11	144.26	9.2166	161.87	11.501	202.00
12	145.60	8.9641	157.43	11.263	197.82
13	146.91	8.9237	156.72	11.060	194.26
14	148.20	8.9520	157.22	10.891	191.28
15	149.43	8.7116	153.00	10.728	188.43
16	150.60	8.5247	149.71	10.577	185.76
17	151.78	8.6565	152.03	10.451	183.56
18	152.91	8.5017	149.31	10.331	181.45
19	154.02	8.4515	148.43	10.221	179.52
20	155.16	8.8965	156.24	10.146	178.20
21	156.55	11.130	195.48	10.190	178.96

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 81237.9 t_o = 123.10 F t_s = 210.44 F

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	126.00	28.425	499.24	28.428	499.28
2	128.25	25.642	450.35	26.850	471.57
3	130.34	12.195	214.18	19.680	345.64
4	132.24	11.252	197.62	16.864	296.18
5	134.03	11.003	193.25	15.397	270.41
6	135.71	10.501	184.44	14.410	253.08
7	137.32	10.286	180.65	13.710	240.78
8	138.87	9.9990	175.61	13.164	231.21
9	140.35	10.056	176.61	12.770	224.29
10	141.82	9.7271	170.83	12.415	218.04
11	143.20	9.6872	170.13	12.135	213.13
12	144.53	9.4232	165.49	11.881	208.67
13	145.83	9.3088	163.49	11.659	204.76
14	147.09	9.2877	163.11	11.469	201.42
15	148.31	9.0891	159.63	11.292	198.32
16	149.49	9.0641	159.19	11.138	195.61
17	150.65	9.0802	159.47	11.004	193.26
18	151.78	8.9246	156.74	10.875	191.01
19	152.87	8.8160	154.83	10.755	188.90
20	154.05	9.7417	171.09	10.697	187.87
21	155.43	11.608	203.87	10.736	188.55

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 91539.1 t_o = 125.30 F t_s = 211.35 F

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	127.88	29.001	509.34	29.003	509.38
2	129.95	26.969	473.66	27.769	487.71
3	131.84	12.652	222.21	20.372	357.80
4	133.59	11.742	206.23	17.488	307.14
5	135.22	11.378	199.83	15.959	280.28
6	136.73	10.745	188.72	14.908	261.84
7	138.17	10.446	183.46	14.152	248.55
8	139.57	10.191	179.00	13.571	238.34
9	140.89	10.126	177.84	13.136	230.70
10	142.19	9.6762	169.94	12.733	223.63
11	143.43	9.6832	170.06	12.422	218.16
12	144.60	9.3232	163.74	12.133	213.09
13	145.76	9.3501	164.21	11.893	208.87
14	146.90	9.2654	162.72	11.683	205.19
15	147.99	9.0513	158.96	11.488	201.76
16	149.05	9.0786	159.44	11.322	198.85
17	150.11	9.1391	160.50	11.180	196.36
18	151.13	8.8807	155.97	11.039	193.88
19	152.13	8.9310	156.85	10.916	191.72
20	153.15	9.2599	162.63	10.824	190.10
21	154.43	11.807	207.37	10.866	190.85

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 135209.5 t_o = 126.30 F t_s = 211.38 F

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	128.61	38.770	680.91	38.772	680.96
2	130.44	35.502	623.52	36.866	647.48
3	132.17	17.168	301.52	27.224	478.14
4	133.78	16.102	282.81	23.504	412.80
5	135.33	16.008	281.15	21.622	379.75
6	136.77	15.094	265.09	20.304	356.59
7	138.15	14.787	259.71	19.365	340.11
8	139.50	14.470	254.14	18.644	327.44
9	140.78	14.472	254.18	18.114	318.14
10	142.04	13.854	243.32	17.616	309.38
11	143.25	13.979	245.52	17.242	302.82
12	144.41	13.535	237.72	16.894	296.71
13	145.55	13.547	237.92	16.603	291.60
14	146.66	13.315	233.86	16.339	286.97
15	147.73	13.124	230.51	16.100	282.76
16	148.77	13.087	229.85	15.891	279.10
17	149.81	13.194	231.72	15.714	275.99
18	150.82	12.955	227.52	15.544	272.99
19	151.80	12.814	225.06	15.384	270.19
20	152.80	13.271	233.07	15.265	268.10
21	154.03	16.729	293.81	15.329	269.23

Table 1 (Continued). Summary Tabulation of No-Sound Data

Reynolds Number = 204570.7 t_o = 119.60 F t_s = 211.10 F

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	121.88	53.403	937.91	53.406	937.96
2	123.71	49.247	864.92	50.941	894.67
3	125.46	24.135	423.88	37.816	664.15
4	127.09	22.508	395.31	32.694	574.20
5	128.65	22.292	391.52	30.082	528.33
6	130.11	21.230	372.87	28.293	496.91
7	131.53	20.849	366.18	27.025	474.64
8	132.88	20.164	354.14	26.014	456.88
9	134.19	20.289	356.33	25.286	444.10
10	135.47	19.378	340.34	24.595	431.96
11	136.70	19.531	343.03	24.075	422.82
12	137.87	18.858	331.21	23.585	414.22
13	139.04	18.854	331.13	23.175	407.01
14	140.17	18.654	327.62	22.811	400.64
15	141.26	18.254	320.59	22.472	394.67
16	142.33	18.253	320.58	22.180	389.54
17	143.39	18.386	322.92	21.932	385.18
18	144.42	18.075	317.45	21.693	380.99
19	145.43	17.863	313.73	21.469	377.06
20	146.58	20.897	367.01	21.427	376.32
21	147.88	23.940	420.46	21.539	378.30

Table 2. Summary Tabulation of Sound Data

Reynolds Number = 16103.9

Max. SPL = 156.9 db

t_o = 118.20 F

t_s = 211.29 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	123.67	10.062	176.72	10.065	176.77
2	127.41	8.1555	143.23	9.0778	159.43
3	130.63	3.6717	64.485	6.4371	113.05
4	133.29	3.0885	54.244	5.3232	93.492
5	135.69	2.9302	51.463	4.7283	83.042
6	137.89	2.7571	48.423	4.3340	76.119
7	139.91	2.5948	45.572	4.0418	70.987
8	141.75	2.4231	42.558	3.8069	66.861
9	143.40	2.2626	39.739	3.6150	63.490
10	145.07	2.2638	39.759	3.4595	60.759
11	146.72	2.3686	41.599	3.3494	58.825
12	148.34	2.3724	41.666	3.2588	57.234
13	149.87	2.2794	40.033	3.1752	55.767
14	151.30	2.1764	38.224	3.0967	54.387
15	152.65	2.1140	37.128	3.0248	53.125
16	154.03	2.2230	39.043	2.9702	52.166
17	155.42	2.2887	40.196	2.9263	51.394
18	156.79	2.2927	40.267	2.8875	50.713
19	158.04	2.1504	37.768	2.8452	49.970
20	159.41	2.4171	42.452	2.8213	49.550
21	160.89	2.6857	47.169	2.8131	49.406

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 16133.2

Max. SPL = 160.1 db

t_o = 117.10 F

t_s = 211.16 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	122.69	10.153	178.32	10.156	178.38
2	126.44	8.1005	142.26	9.1002	159.82
3	129.59	3.5383	62.142	6.3846	112.13
4	132.18	2.9727	52.209	5.2503	92.211
5	134.63	2.9494	51.800	4.6779	82.158
6	136.94	2.8628	50.280	4.3142	75.770
7	139.03	2.6488	46.522	4.0341	70.851
8	140.85	2.3537	41.339	3.7905	66.572
9	142.38	2.0812	36.552	3.5786	62.851
10	143.98	2.1296	37.403	3.4122	59.929
11	145.68	2.4077	42.287	3.3106	58.144
12	147.34	2.3931	42.030	3.2254	56.647
13	148.93	2.3265	40.860	3.1485	55.297
14	150.28	2.0241	35.550	3.0604	53.749
15	151.53	1.9244	33.798	2.9777	52.298
16	152.90	2.1718	38.143	2.9229	51.335
17	154.35	2.3459	41.201	2.8854	50.677
18	155.75	2.2947	40.301	2.8492	50.040
19	156.99	2.0960	36.812	2.8060	49.281
20	158.31	2.2804	40.051	2.7770	48.773
21	160.09	3.1814	55.874	2.7955	49.097

Table 2 (Continued). Summmary Tabulation of Sound Data

Reynolds Number = 16034.0

Max. SPL = 162.6 db

t_o = 120.00 F

t_s 211.20 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	125.50	10.311	181.10	10.315	181.16
2	129.22	8.2905	145.60	9.2716	162.83
3	132.30	3.5730	62.753	6.4896	113.97
4	134.80	2.9690	52.144	5.3195	93.426
5	137.24	3.0321	52.253	4.7502	83.427
6	139.59	3.0091	52.849	4.4008	77.291
7	141.68	2.7547	48.381	4.1237	72.424
8	143.48	2.4045	42.230	3.8745	68.047
9	144.90	2.0074	35.255	3.6434	63.989
10	146.39	2.0570	36.128	3.4615	60.795
11	148.17	2.6026	45.710	3.3740	59.258
12	149.90	2.5887	45.465	3.3006	57.968
13	151.45	2.3665	41.563	3.2207	56.566
14	152.71	1.9817	34.805	3.1239	54.864
15	153.84	1.8035	31.675	3.0281	53.183
16	155.18	2.1927	38.511	2.9713	52.186
17	156.68	2.5327	44.483	2.9424	51.677
18	158.07	2.3786	41.776	2.9076	51.067
19	159.27	2.1123	37.098	2.8621	50.267
20	160.55	2.3067	40.513	2.8315	49.730
21	162.75	4.0995	71.999	2.8926	50.803

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 22428.8 t_o = 110.00 F

t_s = 211.25 F

Max. SPL = 156.0 db Frequency = 222.0 cps

Chamber Number	t	Local Data		Average Data	
		h_x	Nu_x	h_{1m}	Nu_{1m}
1	115.26	12.149	213.38	12.152	213.43
2	118.83	9.7457	171.16	10.913	191.66
3	122.16	4.6980	82.510	7.8747	138.30
4	125.18	4.3642	76.649	6.7030	117.72
5	127.91	4.1315	72.562	6.0611	106.45
6	130.39	3.8843	68.220	5.6240	98.774
7	132.84	3.9253	68.939	5.3361	93.718
8	135.07	3.6522	64.144	5.0900	89.396
9	137.15	3.5921	63.088	4.9020	86.093
10	139.19	3.4669	60.889	4.7356	83.170
11	141.10	3.4623	60.809	4.6063	80.900
12	142.89	3.2916	57.811	4.4843	78.758
13	144.61	3.2431	56.959	4.3781	76.893
14	146.28	3.2293	56.716	4.2871	75.295
15	147.86	3.1220	54.832	4.2015	73.791
16	149.38	3.1094	54.610	4.1271	72.483
17	150.87	3.1048	54.530	4.0614	71.330
18	152.30	3.0467	53.509	3.9996	70.246
19	153.66	2.9512	51.832	3.9395	69.189
20	155.20	3.4422	60.455	3.9114	68.696
21	156.79	3.6760	64.562	3.8977	68.455

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 22402.6

Max. SPL = 159.4 db

t_o = 107.50 F

t_s = 211.28 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{1m}	Nu_{1m}
1	112.58	11.368	199.66	11.370	199.70
2	116.22	9.6007	168.61	10.435	183.27
3	119.57	4.5838	80.505	7.5738	133.01
4	122.61	4.2521	74.680	6.4647	113.53
5	125.41	4.0892	71.819	5.8710	103.11
6	127.96	3.8512	67.639	5.4649	95.979
7	130.36	3.7175	65.290	5.1693	90.788
8	132.63	3.5863	62.986	4.9377	36.721
9	134.78	3.5750	62.788	4.7663	83.709
10	136.87	3.4355	60.338	4.6117	80.994
11	138.87	3.4774	61.073	4.4961	78.964
12	140.70	3.2637	57.319	4.3816	76.953
13	142.48	3.2148	56.462	4.2816	75.197
14	144.15	3.1075	54.577	4.1888	73.567
15	145.74	3.0463	53.502	4.1048	72.092
16	147.31	3.0738	53.986	4.0344	70.857
17	148.84	3.0909	54.286	3.9737	69.789
18	150.34	3.0644	53.820	3.9181	68.814
19	151.82	3.0904	54.277	3.8702	67.972
20	153.47	3.3547	58.919	3.8412	67.462
21	155.03	3.6863	64.742	3.8315	67.292

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 22718.3

Max. SPL = 161.4 db

t_o = 108.50

t_s = 211.04 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	113.43	11.390	200.04	11.392	200.08
2	116.90	9.4148	165.35	10.359	181.94
3	120.10	4.4958	78.960	7.4928	131.59
4	123.02	4.1959	73.693	6.3920	112.26
5	125.70	4.0282	70.747	5.8014	101.88
6	128.16	3.8024	66.781	5.3994	94.830
7	130.50	3.6998	64.980	5.1118	89.778
8	132.67	3.5158	61.748	4.8785	85.681
9	134.71	3.4673	60.896	4.7012	82.567
10	136.70	3.3358	58.586	4.5428	79.785
11	138.62	3.4085	59.863	4.4273	77.756
12	140.43	3.2872	57.734	4.3211	75.891
13	142.16	3.1883	55.996	4.2240	74.186
14	143.76	3.0338	53.282	4.1300	72.535
15	145.29	2.9614	52.011	4.0442	71.028
16	146.80	3.0165	52.979	3.9741	69.797
17	148.30	3.0571	53.693	3.9150	68.759
18	149.73	2.9794	52.327	3.8580	67.757
19	151.08	2.8506	50.066	3.8002	66.743
20	152.56	3.2239	56.622	3.7680	66.178
21	154.08	3.4007	59.727	3.7479	65.824

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 30180.5

Max. SPL = 156.5 db

t_o = 119.10 F

t_s = 211.18 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	123.50	15.226	267.41	15.229	267.46
2	126.68	12.932	227.12	14.010	246.05
3	129.42	5.7807	101.52	9.9893	175.44
4	131.77	5.0344	88.419	8.3394	146.46
5	133.86	4.6701	82.020	7.4267	130.43
6	135.74	4.3107	75.708	6.8035	119.49
7	137.52	4.1471	72.835	6.3569	111.64
8	139.21	4.0026	70.298	6.0145	105.63
9	140.83	4.0323	70.819	5.7666	101.27
10	142.43	3.9200	68.846	5.5531	97.529
11	143.94	3.8882	68.288	5.3847	94.572
12	145.36	3.7205	65.343	5.2308	91.867
13	146.76	3.7428	65.735	5.1036	89.634
14	148.11	3.6558	64.207	4.9893	87.626
15	149.42	3.6313	63.776	4.8894	85.873
16	150.68	3.6086	63.377	4.8022	84.340
17	151.93	3.6359	63.857	4.7272	83.023
18	153.15	3.6022	63.265	4.6586	81.818
19	154.34	3.5811	62.895	4.5965	80.727
20	155.62	3.9439	69.266	4.5599	80.085
21	157.14	4.8248	84.737	4.5705	80.271

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 30070.3

t_o = 120.30 F

t_s = 211.18 F

Max. SPL = 159.8 db

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	124.55	14.844	260.71	14.847	260.76
2	127.57	12.445	218.58	13.583	238.56
3	130.22	5.6241	98.775	9.6944	170.26
4	132.49	4.9062	86.167	8.0999	142.25
5	134.52	4.5722	80.302	7.2221	126.84
6	136.35	4.2083	73.910	6.6194	116.25
7	138.07	4.0343	70.855	6.1847	108.62
8	139.70	3.8990	68.478	5.8523	102.78
9	141.28	3.9544	69.450	5.6148	98.613
10	142.85	3.8479	67.580	5.4104	95.022
11	144.32	3.8153	67.008	5.2490	92.187
12	145.70	3.6241	63.649	5.0987	89.547
13	147.04	3.5893	63.039	4.9698	87.285
14	148.36	3.5836	62.939	4.8603	85.361
15	149.63	3.5384	62.145	4.7631	83.655
16	150.87	3.5357	62.097	4.6794	82.185
17	152.09	3.5602	62.528	4.6074	80.920
18	153.27	3.4869	61.240	4.5392	79.721
19	154.41	3.4384	60.388	4.4758	78.609
20	155.70	3.9799	69.899	4.4475	78.111
21	157.24	4.8802	85.710	4.4664	78.444

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 29548.9

Max. SPL = 163.5 db

t_o = 118.40 F

t_s = 211.27 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	122.66	14.301	251.18	14.304	251.22
2	125.64	11.768	206.68	12.983	228.02
3	128.27	5.3638	94.205	9.2604	162.63
4	130.58	4.7690	83.758	7.7641	136.36
5	132.62	4.4035	77.339	6.9278	121.67
6	134.47	4.0897	71.827	6.3599	111.69
7	136.20	3.8789	68.125	5.9428	104.37
8	137.80	3.6517	67.134	5.6099	98.527
9	139.35	3.7067	65.101	5.3721	94.350
10	140.93	3.6913	64.830	5.1776	90.935
11	142.43	3.7116	65.186	5.0291	88.325
12	143.84	3.5418	62.204	4.8913	85.905
13	145.18	3.4265	60.179	4.7663	83.710
14	146.48	3.3781	59.329	4.6558	81.786
15	147.76	3.3833	59.420	4.5632	80.143
16	149.04	3.4881	61.261	4.4896	78.851
17	150.29	3.4569	60.713	4.4230	77.681
18	151.48	3.3494	58.826	4.3576	76.533
19	152.61	3.2422	56.942	4.2936	75.408
20	153.90	3.7837	66.453	4.2646	74.899
21	155.52	4.8754	85.626	4.2924	75.388

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 44138.8

Max. SPL = 155.2 db

t_o = 120.00 F

t_s = 210.25 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	123.72	19.205	337.31	19.208	337.36
2	126.46	16.578	291.16	17.795	312.53
3	129.02	7.9661	139.90	12.987	228.09
4	131.35	7.3927	129.83	11.118	195.27
5	133.45	6.9062	121.29	10.066	176.79
6	135.32	6.3468	111.46	9.3201	163.68
7	137.12	6.2163	109.17	8.7958	154.47
8	138.90	6.2343	109.49	8.4204	147.88
9	140.63	6.3739	111.94	8.1615	143.34
10	142.31	6.0927	107.00	7.9203	139.10
11	143.85	5.9239	104.04	7.7170	135.53
12	145.29	5.6178	98.665	7.5219	132.10
13	146.73	5.6815	99.784	7.3637	129.32
14	148.16	5.8250	102.30	7.2406	127.16
15	149.55	5.7312	100.65	7.1283	125.19
16	150.86	5.6007	98.364	7.0233	123.35
17	152.12	5.4917	96.450	6.9243	121.61
18	153.34	5.3824	94.531	6.8300	119.95
19	154.56	5.4913	96.443	6.7522	118.58
20	155.82	5.8290	102.37	6.7003	117.67
21	157.28	6.9637	122.30	6.7097	117.84

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 43962.4 t_o = 121.70 F

t_s = 210.25 F

Max. SPL = 157.6 db Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	125.24	18.601	326.69	18.604	326.74
2	127.85	16.019	281.35	17.217	302.39
3	130.29	7.7030	135.28	12.563	220.65
4	132.53	7.1938	126.34	10.769	189.14
5	134.52	6.6359	116.54	9.7376	171.02
6	136.28	6.0289	105.88	8.9940	157.96
7	137.96	5.8874	103.39	8.4698	148.75
8	139.66	6.0183	105.69	8.1105	142.44
9	141.35	6.2792	110.28	7.8780	138.36
10	142.96	5.8650	103.00	7.6434	134.23
11	144.41	5.6331	98.933	7.4390	130.65
12	145.78	5.3662	94.246	7.2466	127.27
13	147.15	5.4404	95.549	7.0914	124.54
14	148.52	5.5733	97.884	6.9701	122.41
15	149.84	5.5026	96.642	6.8610	120.49
16	151.08	5.3003	93.088	6.7540	118.62
17	152.27	5.2011	91.347	6.6539	116.86
18	153.44	5.1562	90.558	6.5623	115.25
19	154.61	5.2556	92.303	6.4865	113.92
20	155.83	5.6615	99.433	6.4398	113.10
21	157.27	6.8120	119.63	6.4547	113.36

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 43617.8

Max. SPL = 159.6 db

t_o = 125.50 F

t_s = 210.34 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	128.90	18.572	326.18	18.574	326.22
2	131.37	15.806	277.61	17.103	300.38
3	133.76	7.8451	137.78	12.572	220.81
4	135.94	7.3090	128.36	10.813	189.91
5	137.84	6.5903	115.74	9.7595	171.40
6	139.52	6.0076	105.51	9.0075	158.19
7	141.12	5.8232	102.27	8.4706	148.76
8	142.74	5.9664	104.78	8.1038	142.32
9	144.31	6.0895	106.94	7.8492	137.85
10	145.87	5.9213	103.99	7.6241	133.90
11	147.27	5.6144	98.606	7.4199	130.31
12	148.58	5.3735	94.374	7.2298	126.97
13	149.90	5.4690	96.051	7.0784	124.31
14	151.25	5.7344	100.71	6.9703	122.41
15	152.54	5.5813	98.024	6.8667	120.60
16	153.75	5.3743	94.388	6.7642	118.79
17	154.89	5.2075	91.459	6.6639	117.03
18	156.01	5.1577	90.584	6.5718	115.42
19	157.14	5.2891	92.893	6.4973	114.11
20	158.33	5.7431	100.86	6.4543	113.35
21	159.74	7.0041	123.01	6.4779	113.77

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 43424.4 t_o = 124.20 F

t_s = 210.44 F

Max. SPL = 161.7 db Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	127.62	18.265	320.78	18.267	320.83
2	130.07	15.264	268.09	16.690	293.12
3	132.43	7.5790	133.10	12.232	214.83
4	134.65	7.2130	126.68	10.553	185.35
5	136.52	6.3446	111.42	9.5039	166.91
6	138.18	5.7772	101.46	3.7573	153.80
7	139.76	5.5901	98.179	8.2237	144.43
8	141.37	5.7613	101.18	7.8632	138.10
9	143.01	6.1846	108.62	7.6495	134.34
10	144.57	5.7838	101.58	7.4316	130.52
11	145.97	5.4470	95.666	7.2300	126.98
12	147.28	5.2012	91.348	7.0417	123.67
13	148.59	5.2769	92.678	6.8901	121.01
14	149.95	5.5879	98.139	6.7854	119.17
15	151.29	5.6452	99.146	6.6996	117.66
16	152.50	5.2204	91.686	6.5980	115.88
17	153.65	5.0774	89.174	6.5000	114.15
18	154.78	5.0344	88.419	6.4104	112.58
19	155.90	5.1452	90.365	6.3369	111.29
20	157.14	5.7696	101.33	6.3038	110.71
21	158.56	6.7831	119.13	6.3240	111.06

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 43467.4

Max. SPL = 163.4 db

t_o = 124.20 F

t_s = 210.71 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	127.58	17.991	315.98	17.993	316.02
2	129.97	14.839	260.62	16.348	287.12
3	132.29	7.4209	130.33	11.980	210.41
4	134.48	7.1116	124.90	10.351	181.80
5	136.32	6.2255	109.33	9.3227	163.73
6	137.95	5.6095	98.518	8.5791	150.67
7	139.49	5.4116	95.043	8.0457	141.30
8	141.05	5.5570	97.597	7.6817	134.91
9	142.69	6.1437	107.90	7.4853	131.46
10	144.24	5.6631	99.460	7.2725	127.72
11	145.58	5.2164	91.615	7.0641	124.06
12	146.85	4.9859	87.567	6.8715	120.68
13	148.13	5.0744	89.210	6.7174	117.97
14	149.46	5.4230	95.243	6.6134	116.15
15	150.77	5.4594	95.883	6.5267	114.62
16	151.97	5.1283	90.067	6.4306	112.94
17	153.10	4.9028	86.108	6.3323	111.21
18	154.20	4.8328	84.879	6.2408	109.60
19	155.32	5.0354	88.437	6.1707	108.37
20	156.51	5.4575	95.850	6.1301	107.66
21	157.94	6.7888	119.23	6.1593	108.17

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 43442.6 t_o = 124.10 F

t_s = 210.59 F

Max. SPL = 164.5 db Frequency = 222.0 cps

Chamber Number	t	Local Data		Average Data	
		h_x	Nu_x	h_{1m}	Nu_{1m}
1	127.46	17.903	314.43	17.905	314.47
2	129.82	14.648	257.27	16.213	284.75
3	132.12	7.3202	128.56	11.862	208.34
4	134.29	7.0515	123.84	10.253	180.07
5	136.10	6.1045	107.21	9.2188	161.90
6	137.71	5.5430	97.351	8.4828	148.98
7	139.25	5.3792	94.474	7.9600	139.80
8	140.80	5.5295	97.114	7.6044	133.55
9	142.45	6.1393	107.82	7.4169	130.26
10	143.99	5.6343	98.955	7.2086	126.60
11	145.36	5.3129	93.310	7.0159	123.22
12	146.63	4.9585	87.086	6.8252	119.87
13	147.90	5.0460	88.623	6.6726	117.19
14	149.24	5.4210	95.209	6.5719	115.42
15	150.56	5.5074	96.726	6.4916	114.01
16	151.76	5.0916	89.424	6.3954	112.32
17	152.89	4.9250	86.497	6.3006	110.65
18	153.98	4.7881	84.093	6.2084	109.03
19	155.09	4.9580	87.077	6.1359	107.76
20	156.35	5.7697	101.33	6.1133	107.36
21	157.77	6.7276	118.15	6.1404	107.84

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 51587.7

Max. SPL = 156.1 db

t_o = 117.50 F

t_s = 210.45 F

Frequency = 222.0 cps

Chamber Number	t	Local Data		Average Data	
		h_x	Nu_x	h_{lm}	Nu_{lm}
1	121.23	21.705	381.21	21.708	381.26
2	124.00	18.866	331.35	20.171	354.27
3	126.42	8.4995	149.27	14.467	254.08
4	128.54	7.5385	132.39	12.158	213.53
5	130.45	7.0510	123.83	10.886	191.19
6	132.18	6.5092	114.32	10.010	175.80
7	133.80	6.2114	109.09	9.3709	164.57
8	135.37	6.1207	107.49	8.8973	156.26
9	136.88	6.1321	107.69	8.5508	150.17
10	138.36	5.8913	103.46	8.2430	144.77
11	139.74	5.7768	101.45	7.9935	140.30
12	141.04	5.5354	97.218	7.7661	136.39
13	142.34	5.5808	98.015	7.5792	133.11
14	143.61	5.5792	97.987	7.4208	130.33
15	144.84	5.4994	96.586	7.2793	127.84
16	146.04	5.4971	96.545	7.1576	125.70
17	147.21	5.4317	95.397	7.0465	123.75
18	148.34	5.3680	94.278	6.9442	121.96
19	149.46	5.3694	94.302	6.8533	120.36
20	150.69	5.9960	105.30	6.8048	119.51
21	152.38	8.5292	149.79	6.8862	120.94

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number 51571.5

Max. SPL = 159.9 db

t_o = 118.00 F

t_s = 210.45 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{1m}	Nu_{1m}
1	121.65	21.381	375.52	21.384	375.57
2	124.30	18.154	318.84	19.670	345.47
3	126.65	8.2519	144.92	14.090	247.46
4	128.72	7.3714	129.46	11.851	208.13
5	130.55	6.7690	118.88	10.586	185.92
6	132.18	6.1748	108.44	9.7037	170.42
7	133.71	5.8757	103.19	9.0603	159.12
8	135.20	5.7742	101.41	8.5821	150.72
9	136.67	5.9522	104.53	8.2524	144.93
10	138.09	5.6309	98.895	7.9492	139.61
11	139.41	5.5183	96.918	7.7035	135.29
12	140.65	5.2630	92.433	7.4779	131.33
13	141.89	5.2811	92.751	7.2903	128.03
14	143.12	5.3897	94.658	7.1397	125.39
15	144.32	5.3236	93.498	7.0059	123.04
16	145.49	5.2878	92.869	6.8885	120.98
17	146.60	5.1427	90.321	6.7764	119.01
18	147.69	5.0920	89.431	6.6739	117.21
19	148.73	4.9253	86.502	6.5736	115.45
20	149.99	6.0990	107.11	6.5452	114.95
21	151.56	78024	137.03	6.6037	115.98

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 51350.4

Max. SPL = 163.0 db

t_o = 119.00 F

t_s = 210.45 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	122.66	21.627	379.83	21.630	379.89
2	125.31	18.272	320.91	19.854	348.69
3	127.66	8.3512	146.67	14.232	249.96
4	129.74	7.4684	131.16	11.978	210.36
5	131.57	6.8504	120.31	10.701	187.95
6	133.19	6.1555	108.10	9.7928	171.98
7	134.79	5.8356	102.49	9.1280	160.31
8	136.18	5.8153	102.13	8.6460	151.84
9	137.65	6.0253	105.82	8.3173	146.07
10	139.08	5.7603	101.16	8.0212	140.87
11	140.27	5.0281	88.308	7.7206	135.59
12	141.48	5.1603	90630	6.4843	131.44
13	142.71	5.3012	93.104	7.2978	128.17
14	143.95	5.4560	95.823	7.1517	125.60
15	145.17	5.4626	95.940	7.0268	123.41
16	146.34	5.3639	94.206	6.9130	121.41
17	147.44	5.1573	90.577	6.8004	119.43
18	148.53	5.1196	89.916	6.6980	117.63
19	149.59	5.0909	89.411	6.6055	116.01
20	150.67	5.2753	92.650	6.5325	114.72
21	152.18	7.5763	133.06	6.5805	115.57

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 59901.5 t_o = 124.00 F

Max. SPL = 157.4 db t_s = 210.75 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	127.19	23.219	407.80	23.222	407.85
2	129.57	20.219	355.12	21.595	379.28
3	131.79	9.6884	170.15	15.771	276.98
4	133.83	8.9967	158.00	13.507	237.23
5	135.71	8.6643	152.17	12.296	215.95
6	137.42	8.0480	141.34	11.442	200.95
7	139.05	7.8011	137.00	10.826	190.13
8	140.66	7.8346	137.59	10.386	182.42
9	142.22	7.9427	139.49	10.077	176.98
10	143.76	7.7037	135.29	9.7996	172.10
11	145.20	7.5895	133.29	9.5735	168.13
12	146.53	7.1019	124.72	9.3433	164.09
13	147.87	7.3294	128.72	9.1692	161.03
14	149.21	7.4116	130.17	9.0279	158.55
15	150.50	7.3480	129.05	8.9022	156.34
16	151.74	7.2277	126.94	8.7863	154.31
17	152.95	7.1921	126.31	8.6823	152.48
18	154.11	7.0424	123.68	8.5812	150.71
19	155.26	7.0276	123.42	8.4905	149.11
20	156.50	7.8638	138.11	8.4531	148.46
21	158.06	10.069	176.85	8.5283	149.78

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 61501.6

Max. SPL = 158.4 db

t_o = 128.00 F

t_s = 210.83 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	130.97	23.326	409.68	23.329	409.72
2	133.15	20.001	351.27	21.550	378.48
3	135.19	9.5724	168.11	15.691	275.59
4	137.06	8.9296	156.82	13.432	235.91
5	138.79	8.5204	149.64	12.204	214.35
6	140.35	7.8870	138.51	11.337	199.11
7	141.85	7.6930	135.11	10.720	188.29
8	143.32	7.6762	134.81	10.274	180.44
9	144.78	7.9749	140.06	9.9823	175.31
10	146.19	7.5004	131.72	9.6927	170.23
11	147.51	7.4543	130.91	9.4639	166.21
12	148.76	7.1715	125.95	9.2498	162.45
13	150.00	7.1899	126.27	9.0720	159.33
14	151.22	7.2301	126.98	8.9244	156.73
15	152.41	7.1616	125.77	8.7929	154.42
16	153.56	7.1746	126.00	8.6808	152.46
17	154.66	6.9668	122.35	8.5695	150.50
18	155.74	6.8828	120.88	8.4657	148.68
19	156.75	6.6236	116.23	8.3592	146.81
20	157.89	7.5605	132.78	8.3129	145.99
21	159.30	9.6336	169.19	8.3736	147.06

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 60999.6

Max. SPL = 161.4 db

t_o = 129.70 F

t_s = 210.78 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	132.59	23.131	406.24	23.133	406.29
2	134.69	19.529	342.99	21.228	372.82
3	136.67	9.4156	165.36	15.450	271.35
4	138.51	8.9050	156.39	13.263	232.93
5	140.16	8.2842	145.49	12.019	211.09
6	141.64	7.5552	132.69	11.123	195.36
7	143.05	7.3304	128.74	10.483	184.11
8	144.46	7.4475	130.80	10.038	176.30
9	145.88	7.8575	138.00	9.7611	171.43
10	147.26	7.4507	130.85	9.4909	166.68
11	148.52	7.2056	126.55	9.2577	162.59
12	149.71	6.8804	120.84	9.0363	158.70
13	150.89	6.9450	121.97	8.8560	155.53
14	152.10	7.2367	127.09	8.7255	153.24
15	153.28	7.1733	125.98	8.6091	151.20
16	154.39	6.9781	122.55	8.4963	149.22
17	155.45	6.7899	119.25	8.3856	147.27
18	156.49	6.6745	117.22	8.2805	145.42
19	157.52	6.8268	119.89	8.1955	143.93
20	158.66	7.6626	134.57	8.1631	143.36
21	160.07	9.7131	170.59	8.2352	144.63

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 61593.8

Max. SPL = 163.0 db

t_o = 127.00 F

t_s = 210.83 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	129.95	22.942	402.93	22.944	402.97
2	132.06	19.065	334.84	20.913	367.29
3	134.07	9.3311	163.88	15.247	267.79
4	135.95	8.8323	155.12	13.103	230.13
5	137.61	8.0623	141.59	11.845	208.03
6	139.09	7.3373	128.86	10.941	192.16
7	140.48	7.0368	123.58	10.283	180.60
8	141.88	7.1671	125.87	9.8271	172.59
9	143.33	7.7098	135.40	9.5577	167.86
10	144.73	7.3686	129.41	9.3013	163.35
11	146.01	7.0284	123.43	9.0696	159.28
12	147.20	6.6390	116.60	8.8435	155.31
13	148.37	6.6756	117.24	8.6572	152.04
14	149.61	7.1239	125.11	8.5334	149.87
15	150.82	7.1065	124.81	8.4260	147.98
16	151.93	6.7558	118.65	8.3107	145.96
17	152.99	6.5198	114.50	8.1949	143.92
18	154.04	6.5018	114.19	8.0910	142.10
19	155.11	6.7528	118.59	8.0124	140.72
20	156.26	7.4441	130.74	7.9783	140.12
21	157.69	9.4948	166.75	8.0488	141.36

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 75452.6

Max. SPL = 160.9 db

t_o = 124.00 F

t_s = 210.40 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	126.94	27.070	475.43	27.073	475.48
2	129.14	23.524	413.16	25.154	441.78
3	131.18	11.192	196.57	18.325	321.84
4	133.08	10.545	185.21	15.725	276.18
5	134.84	10.144	178.17	14.329	251.66
6	136.43	9.3791	164.72	13.334	234.18
7	137.95	9.0725	159.33	12.613	221.52
8	139.44	9.0308	158.60	12.087	212.29
9	140.89	9.2336	162.16	11.726	205.94
10	142.29	8.6597	152.09	11.369	199.67
11	143.63	8.7495	153.66	11.101	194.97
12	144.89	8.3862	147.28	10.847	190.51
13	146.13	8.3206	146.13	10.630	186.69
14	147.38	8.5775	150.64	10.465	183.79
15	148.60	8.5212	149.65	10.319	181.24
16	149.78	8.4233	147.93	10.188	178.93
17	150.91	8.2696	145.23	10.063	176.74
18	151.97	7.8502	137.87	9.9279	174.36
19	153.06	8.1582	143.28	9.8245	172.54
20	154.20	8.7310	153.34	9.7620	171.45
21	155.63	11.328	198.96	9.8341	172.71

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 75396.9

Max. SPL = 162.9 db

t_o = 124.30 F

t_s = 210.40 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{1m}	Average Data Nu_{1m}
1	127.21	26.824	471.12	26.827	471.16
2	129.37	23.238	408.12	24.892	437.17
3	131.38	11.023	193.59	18.109	318.04
4	133.25	10.401	182.67	15.533	272.80
5	134.97	9.9612	174.94	14.139	248.33
6	136.51	9.0862	159.58	13.124	230.50
7	137.97	8.6913	152.64	12.376	217.35
8	139.40	8.6792	152.43	11.834	207.85
9	140.83	9.0339	158.66	11.480	201.62
10	142.24	8.7620	153.88	11.162	196.03
11	143.53	8.4389	148.21	10.884	191.16
12	144.77	8.2040	144.08	10.634	186.77
13	145.99	8.1593	143.30	10.421	183.02
14	147.21	8.3624	146.86	10.255	180.12
15	148.42	8.3950	147.44	10.116	177.67
16	149.61	8.5119	149.49	10.004	175.70
17	150.71	8.0166	140.79	9.8752	173.43
18	151.77	7.7442	136.01	9.7447	171.14
19	152.82	7.9142	138.99	9.6381	169.27
20	153.95	8.5969	150.98	9.5784	168.22
21	155.40	11.364	199.59	9.6614	169.68

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number 76586.0

Max. SPL = 163.6 db

t_o = 118.50 F

t_s = 210.29 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	121.60	26.979	473.84	26.982	473.88
2	123.88	23.041	404.67	24.881	436.99
3	126.01	11.050	194.07	18.116	318.18
4	127.99	10.366	182.07	15.527	272.70
5	129.80	9.8787	173.49	14.115	247.90
6	131.43	9.0081	158.20	13.089	229.89
7	132.96	8.6323	151.60	12.337	216.67
8	134.50	8.7595	153.84	11.812	207.46
9	136.03	9.1337	160.41	11.472	201.49
10	137.52	8.7332	153.38	11.152	195.87
11	138.90	8.4578	148.54	10.877	191.04
12	140.19	8.0356	141.12	10.613	186.39
13	141.47	8.0756	141.83	10.394	182.56
14	142.77	8.3667	146.94	10.231	179.70
15	144.06	8.4130	147.75	10.095	177.30
16	145.27	8.1595	143.30	9.9616	174.95
17	146.44	7.9752	140.06	9.8327	172.69
18	147.56	7.7317	135.79	9.7039	170.42
19	148.68	7.8778	138.35	9.5975	168.56
20	149.89	8.6933	152.67	9.5450	167.63
21	151.43	11.318	198.78	9.6274	169.08

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 75383.6

Max. SPL = 163.8 db

t_o = 124.30 F

t_s = 210.40 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	127.22	27.008	474.34	27.011	474.39
2	129.38	23.136	406.34	24.941	438.04
3	131.38	10.997	193.14	18.121	318.27
4	133.25	10.412	182.88	15.545	273.02
5	134.96	9.8762	173.45	14.128	248.13
6	136.50	9.0501	158.94	13.108	230.22
7	137.94	8.6362	151.67	12.353	216.96
8	139.38	8.6883	152.59	11.816	207.53
9	140.83	9.2070	161.70	11.485	201.71
10	142.24	8.7381	153.46	11.164	196.07
11	143.53	8.4197	147.87	10.884	191.16
12	144.79	8.3020	145.80	10.643	186.92
13	145.99	8.0945	142.16	10.423	183.06
14	147.22	8.3763	147.11	10.259	180.18
15	148.43	8.3888	147.33	10.119	177.72
16	149.57	8.2005	144.02	9.9865	175.39
17	150.66	7.9107	138.93	9.8521	173.03
18	151.72	7.7736	136.52	9.7246	170.79
19	152.77	7.8854	138.49	9.6175	168.91
20	153.90	8.5891	150.85	9.5585	167.87
21	155.30	11.003	193.26	9.6247	169.03

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 80935.2

Max. SPL = 158.9 db

t_o = 123.50 F

t_s = 211.28 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	126.43	28.461	499.85	28.463	499.90
2	128.65	25.064	440.19	26.600	467.17
3	130.71	11.967	210.18	19.442	341.45
4	132.63	11.197	196.66	16.686	293.06
5	134.39	10.720	188.28	15.194	266.85
6	136.02	10.085	177.13	14.166	248.80
7	137.57	9.8170	172.41	13.429	235.86
8	139.11	9.7893	171.92	12.894	226.46
9	140.59	9.9477	174.71	12.520	219.90
10	142.06	9.6143	168.85	12.180	213.92
11	143.43	9.4316	165.64	11.899	208.98
12	144.72	9.0860	159.57	11.636	204.36
13	146.00	9.0812	159.49	11.415	200.49
14	147.26	9.1007	159.83	11.230	197.23
15	148.48	9.0084	158.21	11.064	194.32
16	149.66	8.8925	156.17	10.914	191.68
17	150.81	8.8834	156.01	10.782	189.36
18	151.91	8.6031	151.09	10.648	187.01
19	153.03	8.8598	155.60	10.543	185.17
20	154.23	9.7115	170.56	10.494	184.30
21	155.63	11.696	205.41	10.547	185.24

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 80013.9 t_o = 126.00 F

t_s = 211.20 F

Max. SPL = 161.9 db Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	128.90	28.849	506.67	28.852	506.73
2	131.06	24.950	438.19	26.751	469.82
3	133.07	11.883	208.69	19.479	342.10
4	134.95	11.261	197.79	16.732	293.87
5	136.68	10.779	189.31	15.243	267.71
6	138.24	9.9083	174.01	14.171	248.88
7	139.71	9.5127	167.07	13.383	235.05
8	141.18	9.5566	167.84	12.822	225.20
9	142.63	9.9712	175.12	12.460	218.83
10	144.05	9.4797	166.49	12.111	212.71
11	145.37	9.3319	163.89	11.827	207.72
12	146.61	8.9034	156.37	11.554	202.93
13	147.85	8.9435	157.07	11.329	198.97
14	149.08	9.1536	160.76	11.154	195.90
15	150.30	3.1830	161.27	11.006	193.31
16	151.45	8.9499	157.18	10.864	190.80
17	152.56	8.7417	153.52	10.726	188.38
18	153.64	8.5867	150.80	10.594	186.07
19	154.71	8.6808	152.46	10.483	184.11
20	155.88	9.7329	170.93	10.438	183.32
21	157.27	11.807	207.36	10.500	184.41

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 82073.2

Max. SPL = 163.0 db

t_o = 121.00 F

t_s = 211.10 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	123.98	28.495	500.45	28.497	500.50
2	126.21	24.771	435.06	26.482	465.10
3	128.27	11.761	206.56	19.282	338.64
4	130.19	11.021	193.56	16.522	290.17
5	131.96	10.609	186.33	15.043	264.20
6	133.57	9.7643	171.48	13.982	245.56
7	135.10	9.5055	166.94	13.225	232.26
8	136.60	9.3955	165.01	12.663	222.41
9	138.11	9.8335	172.70	12.304	216.09
10	139.36	9.3556	164.31	11.959	210.04
11	140.92	9.1618	160.90	11.673	205.02
12	142.21	8.7775	154.15	11.403	200.28
13	143.47	8.7714	154.05	11.176	196.29
14	144.74	8.9823	157.75	11.000	193.20
15	145.98	8.8667	155.72	10.841	190.40
16	147.15	8.6880	152.58	10.692	187.79
17	148.30	8.5797	150.68	10.555	185.38
18	149.41	8.4067	147.64	10.423	183.06
19	150.51	8.4817	148.96	10.310	181.07
20	151.72	9.5276	167.33	10.263	180.26
21	153.17	11.728	205.97	10.330	181.43

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 91257.2 t_o = 125.70 F

t_s = 211.26 F

Max. SPL = 160.4 db Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	128.35	29.906	525.24	29.909	525.29
2	130.37	26.387	463.44	27.974	491.31
3	132.23	12.428	218.28	20.370	357.77
4	133.93	11.500	201.97	17.408	305.73
5	135.54	11.278	198.08	15.874	278.79
6	137.04	10.677	187.53	14.827	260.41
7	138.44	10.156	178.37	14.037	246.52
8	139.79	9.8678	173.30	13.426	235.80
9	141.09	9.9100	174.04	12.982	228.01
10	142.36	9.5095	167.01	12.578	220.91
11	143.58	9.5990	168.58	12.274	215.57
12	144.74	9.1579	160.83	11.984	210.47
13	145.86	9.0558	159.04	11.732	206.05
14	146.97	9.0336	158.65	11.517	202.27
15	148.05	8.9937	157.95	11.330	198.98
16	149.11	9.0323	158.63	11.171	196.20
17	150.16	9.0299	158.59	11.032	193.76
18	151.17	8.8164	154.84	10.896	191.36
19	152.14	8.6410	151.76	10.765	189.07
20	153.16	9.2471	162.40	10.680	187.57
21	154.40	12.009	210.92	10.740	188.62

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 91031.0

Max. SPL = 162.9 db

t_o = 128.20 F

t_s = 211.27 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Local Data Nu_x	Average Data h_{lm}	Average Data Nu_{lm}
1	130.78	30.000	526.89	30.003	526.93
2	132.74	26.419	463.99	28.038	492.43
3	134.56	12.569	220.76	20.471	359.54
4	136.24	11.721	205.86	17.547	308.19
5	137.88	11.440	200.91	16.018	281.33
6	139.28	10.729	188.44	14.953	262.63
7	140.65	10.225	179.58	14.153	248.57
8	141.97	9.9386	174.55	13.536	237.73
9	143.24	10.055	176.61	13.097	230.02
10	144.51	9.7745	171.66	12.709	223.21
11	145.71	9.7246	170.79	12.404	217.86
12	146.84	9.2958	163.26	12.114	212.77
13	147.95	9.1771	161.17	11.862	208.33
14	149.02	9.1120	160.03	11.643	204.48
15	150.09	9.1521	160.73	11.458	201.23
16	151.13	9.1695	161.04	11.300	198.46
17	152.14	9.0508	158.95	11.154	195.90
18	153.12	8.8508	155.44	11.012	193.41
19	154.07	8.7162	153.08	10.879	191.08
20	155.06	9.2185	161.90	10.787	189.45
21	156.33	12.159	213.55	10.849	190.54

Table 2 (Continued). Summary Tabulation of Sound Data

Reynolds Number = 136294.9

Max. SPL = 162.7 db

t_o = 128.40 F

t_s = 211.20 F

Frequency = 222.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{lm}	Nu_{lm}
1	130.65	39.288	690.01	39.291	690.06
2	132.40	35.194	618.12	36.995	649.75
3	134.04	16.854	296.01	27.140	476.66
4	135.57	15.946	280.06	23.396	410.91
5	137.05	15.793	277.38	21.489	377.41
6	138.43	15.078	264.82	20.194	354.66
7	139.74	14.491	254.50	19.225	337.64
8	141.00	14.065	247.03	18.466	324.32
9	142.21	14.118	247.96	17.915	314.65
10	143.40	13.592	238.72	17.410	305.78
11	144.58	14.059	246.92	17.065	299.71
12	145.68	13.332	234.16	16.715	293.56
13	146.77	13.279	233.21	16.417	288.33
14	147.82	13.086	229.83	16.150	283.64
15	148.85	13.013	228.56	15.916	279.53
16	149.87	13.146	230.88	15.723	276.15
17	150.86	13.085	229.81	15.550	273.11
18	151.83	12.782	224.49	15.379	270.10
19	152.76	12.539	220.22	15.213	267.19
20	153.71	13.040	229.02	15.091	265.05
21	154.91	16.797	295.00	15.167	266.39

Table 2 (Continued) Summary Tabulation of Sound Data

Reynolds Number = 203614.9 $\qquad$ t_o = 121.80 F

t_s = 211.18 F

Max. SPL = 161.4 db $\qquad$ Frequency = 220.0 cps

Chamber Number	t	Local Data h_x	Nu_x	Average Data h_{1m}	Nu_{1m}
1	123.92	52.970	930.30	52.972	930.35
2	125.69	48.842	857.81	50.525	887.37
3	127.36	23.378	410.59	37.238	654.02
4	128.92	22.123	388.54	32.181	565.19
5	130.42	21.910	384.80	29.602	519.91
6	131.84	21.004	368.90	27.864	489.37
7	133.20	20.493	359.92	26.608	467.32
8	134.52	19.913	349.74	25.622	449.99
9	135.78	19.991	351.10	24.906	437.42
10	137.03	19.199	337.20	24.237	425.68
11	138.23	19.413	340.95	23.741	416.96
12	139.37	18.708	328.57	23.268	408.66
13	140.50	18.714	328.67	22.872	401.71
14	141.61	18.530	325.45	22.523	395.57
15	142.68	18.232	320.20	22.202	389.94
16	143.72	18.254	320.59	21.928	385.13
17	144.76	18.347	322.22	21.693	381.00
18	145.77	18.031	316.68	21.466	377.00
19	146.76	17.789	312.43	21.250	373.22
20	147.73	17.942	315.12	21.066	369.99
21	148.94	22.708	398.82	21.136	371.21

Table 3. Chamber Dimensions

Chamber Number	x_i (ft.)	A_i (ft.^{2})	A_{x_i} (ft.^{2})
1	0.267	0.279	0.279
2	0.527	0.532	0.247
3	1.023	1.033	0.495
4	1.526	1.540	0.502
5	2.022	2.041	0.496
6	2.518	2.542	0.496
7	3.017	3.046	0.498
8	3.520	3.554	0.502
9	4.010	4.049	0.490
10	4.521	4.565	0.511
11	5.016	5.065	0.494
12	5.514	5.568	0.498
13	6.015	6.974	0.500
14	6.516	6.579	0.500
15	7.017	7.085	0.501
16	7.514	7.587	0.496
17	8.013	8.091	0.498
18	8.515	8.597	0.501
19	9.017	9.104	0.501
20	9.518	6.610	0.501
21	10.018	10.115	0.499

BIBLIOGRAPHY

1. Jackson, T. W., Spurlock, J. M., Purdy, K. R., Oliver, C. C. and Johnson, H. L., The Effects of Resonant Acoustic Vibrations on Heat Transfer to Air in Horizontal Tubes, WADC Technical Note 59-330, Wright Air Development Center, 1959.

2. Jackson, T. W., Purdy, K. R., Oliver, C. C., and Johnson, H. L., The Effects of Resonant Acoustic Vibrations on the Local and Overall Heat Transfer Coefficient for Air Flowing Through an Isothermal Horizontal Tube, ARL Technical Report 60-322, Aeronautical Research Laboratories, 1960.

3. Jackson, T. W., Purdy, K. R., and Oliver, C. C., The Effects of Resonant Acoustic Vibrations on the Nusselt Numbers for a Constant Temperature Horizontal Tube, Paper 57, Part 11, 1961 International Heat Transfer Conference, Boulder, Colorado.

4. Spurlock, J. M., The Effects of Acoustic Vibrations on Air in a Resonant Horizontal Tube With and Without Throughflow, Unpublished Ph. D. Thesis, Georgia Institute of Technology, 1961.

5. Jackson, T. W., Harrison, W. B., Boteler, W. C., Free Convection, Forced Convection, and Acoustic Vibrations in a Constant Temperature Vertical Tube, Transactions of the American Society of Mechanical Engineers, Series C, 81, pages 68-74, 1959.

6. Stearns, R. F., Jackson, R. M., Johnson, R. R., and Larson, C. A., Flow Measurement with Orifice Meters, Van Nostrand Co., Inc., New York, 1951.

7. Crocco, L., Harrje, D. T., and Croke, E., Heat Transfer in Oscillating Flow, Progress Report 1 July 1958 to 1 October 1959, Aeronautical Engineering Report No. 483, Princeton University.

8. Jakob, M., Heat Transfer, J. Wiley and Sons, Inc., New York, page 479, Volume 1.

9. Jakob, J., op. cit., page 548, Volume 1.

10. Keenan, J. H., and Keyes, F. G., Thermodynamic Properties of Steam, First Edition, J. Wiley and Sons, New York, 1936.

11. Giedt, W. H., Principles of Engineering Heat Transfer, First Edition, Van Nostrand Co., Inc., New York, 1957.

12. Kubanski, P. N., "Flow Near a Heated Hard Body in a Standing Acoustic Wave," Journal of Technical Physics (U. S. S. R.), Volume 22, pages 585-92, 1952.

13. Chung-Kong Hwu, The Effect of Vibration on Forced Convective Heat Transfer, Unpublished Ph. D. Thesis, University of Cincinnati, 1959.